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NEW SERIES, Vol. I. (1874-5-6.)

PROCEEDINGS

OF THE

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NEW SERIES, VOL. I. PART III.

REPORTS OF MEETINGS AND EXCURSIONS.

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The Society is again indebted to Mr. Stoddart for presenting the cuts and folding plate which illustrate his paper. Also to Mr. Walter Derham, for the two excellent plates of Fossil Encrinites, and to the Editor for the Index to Vol. I.

Geology of the Bristol Coal-field.

PART 8.—CARBONIFEROUS.

Read at the General Meeting, March 4th, 1875.

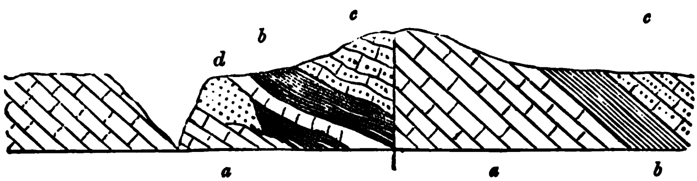
WE now arrive at the principal and most important part of our subject, viz., the coal measures and their adjacent rocks. The various beds of the Carboniferous series may be more extensively displayed in other parts of Great Britain, but in no place are they so well shewn collectively, or so well adapted for study as in our own immediate neighbourhood. Each division is very rich in all the characteristic fossils, in examples of faults, anticlinals, upheavals, denudation, and other types illustrative of Physical geology. Crystallography and Mineralogy are no less fully developed in those crystals and minerals peculiar to the Carboniferous Limestone.

It is principally to these rocks that we owe our Clifton, Cheddar, Mendip, and other exquisite bits of scenery, for which Somersetshire and Devonshire are so celebrated.

We find the Carboniferous follow the Devonian Sandstone gradually and conformably, commencing as argillaceous strata, then

changing into pure massive limestone, and ending in many hundred feet of grits and sandy beds. In several localities to be subsequently described, we find these limestone beds forming immense hollows many miles in diameter that were afterwards filled up by stores of coal, which now constitute directly, or indirectly, so great a source of our national prosperity. Here and there we find some exercise of terrestial force has disjointed and displaced immense thicknesses of rocks, dislocating and twisting them into the most fantastic shapes. Perhaps the most remarkable of these faults, and one that is most fully displayed, is that on the north bank of the Avon. Here is a displacement, vertically, of more than eight hundred feet, dividing the Clifton series into two parts, sinking the one and upheaving the other, till we see apparently, as we walk down the river side, two sections of the same beds. This is explained roughly by fig. 14.

Fig. 14.—*Clifton Fault.*



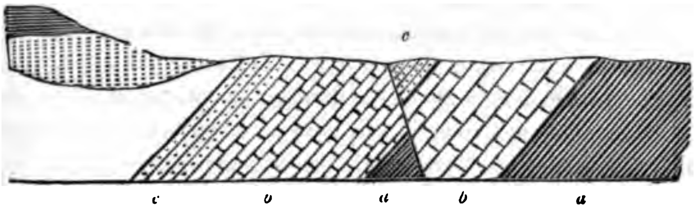
a Massive Limestone.—*b* Upper Limestone Shales.—*c* Millstone Grit.—*d* Magnesian Conglomerate.

The destruction caused by this tremendous convulsion was still more intensified by concluding with an awful lateral pressure which crushed the broken rocks into contortions, mixing them with later formations in the utmost confusion.

With broken masses of limestone we see millstone grit, marls, magnesian conglomerate, and beds of coal mingled together without the slightest reference to order of deposition. Any one walking past this spot will see an unrivalled section more than three hundred feet thick and a quarter of a mile long.

Another well-marked fault is met with in the Wick Rocks, and interfering with the beds of coal, as seen in fig. 15.

FIG. 15.—*Wick Fault.*

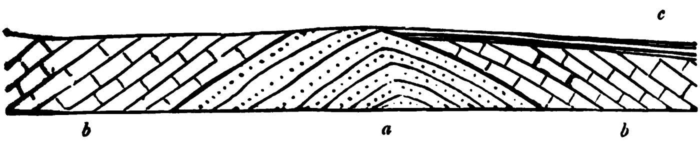


a Devonian.—*b* Carboniferous Limestone.—*c* Millstone Grit.—*d* Lower Coal Measures.—*e* Trias.—*f* Lias.

Other examples are to be met with, but not so well displayed. It is probable that these faults were caused by internal forces beneath the crust of the earth about the commencement of the Triassic period. At any rate, dreadful as were the results to the then existing surface, yet they were the means of bringing within our reach the rich stores of coal. Many of the coal seams lay so deeply that, had not this upheaval of the country taken place, we could not possibly have reached them.

Another variety of the disturbance of strata occurs very frequently. A large mass of older rocks are forced up to the surface through those of later age. We have already noticed some as of Silurian at Purton (*page* 263), and at Tortworth (*page* 267) of Devonian as at Brockley Combe (*page* 268), and of Basalt at Downhead (*page* 270). As seen in fig. 16 representing the rocks through which the Wickwar tunnel passes,

FIG. 16.—*Wickwar Anticlinal*



a Devonian.—*b* Carboniferous Limestone.—*c* Lias.

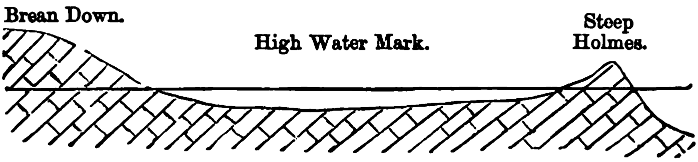
the Devonian sandstone has been forced through a large thickness of limestone, supporting the latter on both sides like the roof of a house, and forming what the geologists call an anticlinal. After this period this peculiar form of upheaval seems to have ceased. All the later faults, though numerous, are mere cracks as it were in the strata, interrupting the continuation of strata only.

The Carboniferous system is divided into two grand divisions—the Limestone rock proper, and the Coal measures. The first and oldest of these is sub-divided into three groups, viz.—

The lower shales about 500 feet in thickness.
The mountain limestone about 2000 do.
The upper shales about 400 do.

In comparatively recent times, the limestone beds became worn down by the action of air and water. A familiar instance of the effects of the long continued wave action must be familiar to all who visit Weston-super-mare. When standing on the summit of Brean Down and looking towards the Steep Holmes at dead low water, the ripples on the water distinctly mark the edges of the limestone strata that are only just covered by the sea. These prove that the island rock was once connected with the shore, but now separated by denudation. Their position is explained by fig. 17.

FIG. 17.—*Section between Weston and Steep Holmes.*



The magnificent and continuous section of the first division of the Carboniferous system is so perfectly exposed on the Gloucestershire side of the Avon, that we will take it as a fine summary of the whole series as observed in the counties of Gloucestershire and Somersetshire. The junction of the Devonian into the Carboniferous strata is complete, and the gradual passage into the lower shales

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with the characteristic beds of fossils can be studied with so much facility and advantage, that we do not hesitate to take the Clifton section as a typical example, following as a guide the accompanying sketch.

The Section commences with Devonian strata 360 feet thick, passing gradually through 500 feet of Lower Limestone shales, then through 2000 feet of Mountain Limestone, and finishing off with 400 feet of Upper Limestone shales and grits, and 1000 feet of Millstone grit.

Every bed may be studied without any dangerous climbing, and with the greatest facility, and in order to facilitate the labours of those who may wish to pay a visit, and who may not be conversant with the locality, the following description, it is hoped, will be amply sufficient to supply the place of a guide. The number of feet indicate the vertical distance from the commencement of the section below Cook's Folly, taking the railway as the datum line, while the numbers of the several beds correspond with those on the diagram. As may easily be imagined, the catalogue of fossiliferous beds is so immensely long that only a few of the most interesting have been taken.

The Devonian beds that commence the first 360 feet of the section, are generally sandstone, containing Mica, but devoid of Carbonate of Lime and Fossils. At the distance of 327 feet are three remarkable beds of quartzose conglomerate 6 feet thick, divided by thin partings of purple and green marls. The pebbles are pieces of quartz which have had their angles completely worn away from long continued water action, and are probably the bed of an ancient river near the sea.

Thirty-three feet above the conglomerates is the first bed that contain any appreciable quantity of lime, and may therefore be considered as the commencement of the true Carboniferous section. The junction of the Old Red and Carboniferous is so gradual that it is impossible to say where one ends and the other begins, but the junction beds may be included between the conglomerates and the bed now mentioned.

Lower Carboniferous Shales.

The figures within [ ] denote the number of feet from the commencement of Section.

1.—[360].—First bed with carbonate of lime in any quantity, and one foot thick.

2.—[385].—*Athyris Roysii* bed of very aluminous limestone 2 feet in thickness. Every part of the bed is crowded with fossils. The most characteristic are:—*Athyris Roysii* (Dav.,) *Spirifera rhomboidea* (Phill.,) *Retzia radialis* (Phill.)

[400].—Hard dark limestone 3 inches thick, resting on 12 inches of yellow marl. The stone is full of minute shells, probably the young of *Naticopsis* and *Rissoa* and *Cytheridæ.*

3.—[408].—*Sanguinolites shales.* Greenish arenaceous shales, very fissile and with abundant and good casts of *Sanguinolites augustata* (Phill.) and *S. complanata* (Phill). A good spot for collecting them is a few yards in the wood.

4.—[413].—*Modiola shales.* This is probably the most important bed of the Lower shales, for many of the fossils are identical with those of the Marwood, Coomhola, Moyola, and the Scotch Coal Measures, so that they go far to support the idea of some of the Upper Devonian belonging rather to the Carboniferous period. Another fact is that the whole of the beds are full of grass-like weeds similar to those of shallow sea shores, or rather to land at a low altitude which is periodically subject to the influence of high tides. Mixed with these plants are immense masses of the cast off valves of entomostraca.

The late Professor Jukes said, "If the Coomhola grits be classed with the Carboniferous series, the so-called Upper Devonian of Devonshire must be classed with the Marwood group as Carboniferous; and if classed with the Devonian, they must be set aside as a distinct sub-group."

The following is a comparative table of these "Modiola" fossils, which appear to render the above mentioned idea conclusive.

	Clifton	Marwood	Coomhola.	Moyola.	Scotch Coal Measures.
Leperditia Okeni	x	—	—	x	x
—— —— var. subrectus...	x	—	—	x	x
Filicites dichotoma	x	—	x	—	—
Knorria dichotoma	x	—	x	—	x
Platycrinus	x	—	x	—	—
Poteriocrinus	x	—	x	—	—
Rhodocrinus	x	—	x	—	—
Serpula omphalodes	x	x	—	x	x
Lingula parallela	x	—	—	x	x
Spirifera disjuncta	—	x	x	x	—
—— bisulcata	x	x	x	x	—
Streptorhynchus crinisria..	x	x	x	x	—
Rhynchonella pleurodon ...	x	x	x	x	—
Cucullœa trapezium	x	x	—	—	—
—— Hardingii	x	x	—	—	—
Modiola Macadami	x	x	x	x	—
Avicula Damnoniensis ...	x	x	x	x	x?
Naticopsis plicistria	x	—	—	x	—
Amblypterus Portlocki ...	x	—	—	x	x
Orthoceras gragarium ...	x	—	x	x	—
Chonetes Hardrensis ...	x	x	—	—	—
Discina nitida	x	x	—	—	—
Athyris Royssii...	x	—	—	—	—
Terebratula hastata	x	—	—	—	—

5.—[433].—*Fenestella bed.* This is light coloured limestone about 1 foot thick, containing plenty of good specimens of *Fenestella flabellata* and other Bryozoa.

6.—[448].—*Bryozoa bed.* This very remarkable deposit is 8 feet thick, of dark red siliceous rock mixed with crystalline limestone. It is one mass of minute casts of fossils in a compound of silica and ferric oxide. They being insoluble in tolerably strong Hydrochloric acid may be easily separated from the lime. A very favorite method of preparing specimens is to suspend a piece of the rock in a beaker of acid till a portion has been dissolved, then removed and dried. The fossils then appear all over the surface, standing out in the most beautiful manner. On gently washing the sediment in the beaker plenty of loose fossils may be obtained ready for the microscope. To give an idea of the immense number of organisms present in the rock, more than one million and a half have been

obtained from only one pound of stone. A description of the Bryozoa bed will be found in the Ann. Nat. Hist., 1861, p. 486. The chief bulk of the fossils are joints of the arms of Encrinites. All of them are very minute, the larger Entrochi from the stems having been washed away, just as in a heap of pebbles, the larger ones roll to the bottom. So here we find the outside of the bank on the opposite side of the river. There we find the particles much larger, mixed with good sized *Productæ*, and sometimes the tooth of a *Psammodus* or *Cladodus*.

The following are fossils that are always present, and may be obtained at any time :—

Ceriopora rhombifera (Goldf.); *Platycrinus lævis* (Mill.); *Poteriocrinus isacobus?* (Aust.); *Leperditia Okeni* (Munst.); *Cypridina ovalis* (Stod.); *Cytherella lunata* (Stod.); *Naticopsis plicistria* (McCoy.), (Young); *Productus* (Sp ?); *Spirorbis triangulatus* (Stod.); *Psammodus porosus* (Ag.): *Cladodus conicus* (Ag.)

7.—[453].—*Palate bed.* This is a breccia 5 feet above the Bryozoa bed, full of fish teeth and coprolites with shells, &c. Very good specimens may be easily obtained, especially from weathered portions. When seen in a freshly made section of the rock, this palate bed has a greyish brown colour, but on exposure to the air it soon changes into a dark reddish brown from oxidation of the iron. The bed is three or four inches in thickness, and lies on eighteen inches of greyish marl. The principal fossils are :—

Discina nitida (Lam.); *Lingula mytiloides* (Dav.); *Naticopsis plicistria* (McCoy.); *Conularia quadrisulcata* (Mill.); *Loxonema rugifera* (Phill.); *Cladodus conicus* (Ag.); *Chomatodus linearis* (Ag.); *Helodus levissimus* (Ag.); *Psammodus porosus* (Ag.); *rugosus* (Ag.)

8.—[495].—*Camarophoria bed.*—This is a 6 inch dark coloured bed of limestone containing in great numbers—

Camarophoria globulina (King.); *Athyris Royssii* (Day.), *lamellosa* (Day.); *Retzia radialis* (Phill.); *Naticopsis plicistria* (McCoy.); *Spirifera duplicicostata* (Dav.)

9.—[506.]—*Buchiana bed* is one of grey limestone from 12 to 20 inches in thickness, and is one mass of mollusca cemented together

with carbonate of lime. Very perfect specimens with the shell may be easily obtained in great numbers and perfection. The following fossils are the most common in a very long list obtainable in this spot.

Chonetes Buchiana (Dav.), *sordida* (Sow.), var *perlata, papilionacea* (Kon.); *Orthis resupinata* (Mart.); *Streptorhyncus crenistria* (Dav.) var. *arachnoidea* (Dalm.): *Sanguinolites transversa* (Portl.)

10.—[520].—*Pleurodon bed.*—This is marked out on account of containing Rhynchonella pleurodon, which is not found in the Clifton rocks so abundantly as in the Derbyshire and many other limestones. The two chief fossils are:—*Rhynchonella pleurodon* (Fisch.); *Cladodus conicus* (Ag.)

11.—[535].—*Fenestella bed,* so called from the remarkable abundance of bryozoa that are found in it. Excellent specimens may be collected on the railway bank, where the little branched polypidoms attract the eye, standing out in relief on the weathered slabs of limestone. From this bed are also collected the heads of Encrinites in a good state of preservation.

Ptylopora pluma (McCoy.), *flustraformis* (Phill.); *Fenestella flabellata* (Lonsd.), *irregularis* (Phill), *polyporata* (Portl), *membranacea* (Lonsd.); *Retepora prisca* (Lonsd.); *Ceriopora interporosa* (Goldf.), *rhombifera* (Gold.); *Streptorhyncus crenistria* (Phill.); *Orthis resupinata* (Mart.); *Encrinites* (various.)

12.—[639].—*Trilobite bed.*—This limestone is very rich in the Phillipsia, of which only the pygidia will probably be found. The pretty little *Chonetes perlata* or as it is sometimes called *C. Hardrensis* is very plentiful. A good spot for this bed is on the top of the hill where it crops up at the back of Avonhurst house, Sneyd Park. Although varieties of the same trilobite, yet the difference as pointed out in Portlock's report on Tyrone, &c., are so marked that the names are retained as a guide to the visitor.

Phillipsia pustulata (Schlot.), var. *Brongniarti* (Fisch.) var. *seminifera* (Phill.); *Chonetes sordida* (Sow.), var. *perlata* (Phill.).

13.—[639].—*Oracanthus bed.*—This is another of our well marked

Clifton beds of fossils. It is about a foot thick, and is extremely rich in Brachiopoda and the sculptured defensive spines of *Oracanthus*. The best opportunity for examining it was a short time ago when an excavation was being made for a house in Sneyd Park, on the road to Stoke Bishop. The limestone weathers easily, and being rather argillaceous the various specimens are more easily and perfectly separated from the matrix than they generally are. The collector should look out for *Rhynchonella acuminata* and *Spirifera Mosquensis*, which are great rarities.

Oracanthus pustulatus (Ag.), *Millerii*, (Ag.), *minor* (Ag.), *Terebratula hastata* (Sow.), var. *ficus*, (McCoy.), var. *sacculus* (Mont.), v. *vesicularis* (DeKon.); *Rhynchonella acuminata* (Sow.); *Spirifera Mosquensis* (Dav.) *glabra* (Dav.) *duplicicostata* (Dav.) *Streptorhyncus crenistria* (Dav.), v. *arachnoidea* (Dalm.); *Strophomena analoga* (Phill.), *Orthis resupinata* (Mart.); *Cypricardia rhombea* (Mus. Pr. G.), *parallela* (Phill.); *Capulus vetustus* (Montf.); *Euomphalus Dionysii* (Goldf.)

14.—[668].—*Spirifer bed.*—This bed is instantly recognised by the abundance of fine specimens of *Spirifera striata* that occur. It is several feet thick and very dark in colour, and is the last illustrative bed of the true Lower Carboniferous Shales that we shall notice. It must not however be supposed that the intervening strata are unfossiliferous. On the contrary the whole of the set of beds is extremely rich, especially in Brachiopoda, so much so that it is extremely difficult to select any special ones. The one now under consideration may be recognised as the commencement of the Black Rock Quarry, and contains chiefly—

Psammodus porosus (Ag.); *Spirifera striata* (Dav.), var. *attenuata, cuspidata* (Mart.); *Producta punctata* (Mart.), *pustulosa* (Phill.); *Athyris Royssii* (Dav.).

Mountain Limestone.

It is difficult and arbitrary to draw any line of demarcation in the Clifton section, so gradually does one part pass into the other. We have, however, for convenience of description, commenced the massive mountain limestone with what is locally known as the

Black Rock Quarry. It is so named from nearly all the beds being very dark in colour, from the presence of bitumen, which sometimes is so plentiful as to give an unpleasant odour to the limestone, especially when rubbed, and sometimes is found as a liquid in small cavities. The quarry is an extensive one, being 770 feet in length, and nearly 300 feet in height. The dip of the beds varies from 20° to 30° to the S.S.E. They are famous, both in this country and elsewhere, for the remains of gigantic fishes that once swarmed in the water of the old carboniferous ocean. Our Museum contains a fine collection of typical specimens, the originals of many of the figures in the large work of Agassiz on fossil fishes. The strata in this quarry are extremely regular and uniform. At the top of the eastern extremity is a singular deposit of cherty ironstone, which appears to have been the result of decomposition. It is full of vacuoles, as if caused by the escape of gases, but no trace of fossils can be seen.

[899].—*Encrinite beds.*—These attain a thickness of 112 feet, and constitute a very large part of the quarry. The stone is one complete mass of the stems, arms and heads of these exquisitely beautiful echinoderms, the sea lilies. The stone, when polished shews the forms in the most perfect manner, and are very favourite specimens and in great request for ornamental work. In the centre of these Encrinital Beds is one in which the largest specimens of Trilobites have been found. It is singular that in this one layer there should have been so many, when they are absent in the others. Nearly all the species of Encrinites yet found have been noticed in this spot.

Agathocrinus planus (Mill.); *Dichocrinus radiatus* (Aust.); *Poteriocrinus conicus* (Phill.), *crassus* (Mill.), *isacobus* (Aust.), *plicatus* (Aust.), *pentangularis* (Mill.), *tenuis* (Mill.), *rostratus* (Aust.), *Rhodocrinus costatus* (Aust.); *granulatus* (Aust.), *verus* (Mill.); *Platycrinus granulatus* (Mill.), *levis* (Mill.), *rugosus* (Mill.), *striatus* (Mill.), *trigintidactylus* (Aust.); *Actinocrinus triacontadactylus* (Aust.)

15 —[961].—*Fish beds.*—At this spot are three beds, so remarkably uniform in thickness and parallelism as to be strikingly

noticeable to anyone passing, and therefore, form a capital guide to this wonderful deposit of Ichthyodorulites. The defensive spines of *Ctenacanthus* sometimes attain a length of 20 inches or two feet. These formidal weapons formed part of the dorsal fins of immense sharks, with grinding teeth like those found near Port Jackson, in Australia. In consequence of these fishes being cartilaginous in their structure, only these spines and the teeth have been preserved, the soft portions having probably disappeared.

The following is a list of fossil contents :—

Cladodus conicus (Ag.), *Milleri* (Ag.), *mirabilis* (Ag.); *Deltoptychius acutus* (Ag.); *Tomodus convexus* (Ag.); *Chomatodus cinctus* (Ag.), *linearis* (Ag.); *Cochliodus contortus* (Ag.); *Ctenacanthus brevis* (Ag.), *major* (Ag.), *tenuistriatus* (Ag.); *Helodus gibberulus* (Ag.), *lævissimus* (Ag.), *subteres* (Ag.), *turgidus* (Ag.); *Onchus hamatus* (Ag.), *sulcatus* (Ag.); *Oracanthus Milleri* (Ag.), *minor* (Ag.), *pustulosus* (Ag.); *Orodus cinctus* (Ag.), *ramosus* (Ag.); *Psammodus porosus* (Ag.), *rugosus* (Ag.).

A long series of interesting beds follow to the end of the quarry, and terminate in a deep ravine leading to the summit of Durdham Down, near what is called the Sea Wall, from which a magnificent panorama is beheld, comprising the fine anchorage ground of Kingroad, backed up by the Welsh Hills.

It is on the side of this ravine that a botanical rarity may be gathered, *Grimmia orbicularis*, a round fruited moss.

On passing the opening of this ravine, we come to a singular series of beds, 167 feet in thickness, of Oolitic limestone, so full of false joints as to give the beds the appearance of having a vertical position, although they really dip 30°. The oölitic structure is extremely fine, each granule having in its centre a minute speck of sand, A great number of microscopical examinations have been made, but have hitherto failed in finding any organic nucleus. On passing these, we come to more regular beds, containing fossils, but only stay to notice one (16).—[1433], having a brown colour, situated 44 feet above the oolitic strata just mentioned, and is entirely composed of myriads of the valves of *Terebratula hastata*, and 6 inches thick.

17.—[1526].—*Aranea bed*, or grey limestone, full of the *Lithostrotion aranea*. The delicate web-like tracery of the septa are shewn very distinctly. It contains a small branched coral whose name has not been definitely determined

Lithostrotion aranea (Edwds.), *irregulare* (Edwds.), *junceum* (Edwds.); *Producta punctata* (Mart).

We now come to the Great Quarry, another extensive section, 1185 feet long, and the same height as the Black Rock. Here the limestone is generally lighter in colour, and, in some places, very bituminous. Between the limestone beds we frequently find cubic crystals of the Fluor Spar. At the western end is a very singular fracture of the beds by subsidence. During the progress of deposition, a portion has evidently been washed away, letting the superincumbent roof of five or six beds fall in; this was evidently not a recent occurrence, because the subsequent thickness of some 200 feet was afterwards regular, and shows no sign of disturbance.

18.—[1539].—*Longispinosus bed* occurs about 15 feet before the commencement of the Great Quarry. It is a smooth, thin, and argillaceous bed completely covered with Trilobites, a Productus with very long spines, Bryozoa, and other organisms.

Producta longispinosa (Sow.); *Phillipsia pustulata* (Schloth.); *Ceriopora rhombifera* (Goldf.) *Lithostrotion junceum* (Edw.); *Entomostraca; Foraminifera.*

19.—[1552].—*Euomphalus bed* is one of the first beds of solid limestone with which we meet in the quarry. It is a rather light coloured limestone, and very fossiliferous, and contains some good specimens of Euomphalus and Producta.

Euomphalus nodosus (Sow.), *calyx* (Phill.); *Producta Martini* (Sow.), *Cora* (D'Orb.); *Rhynchonella acuminata* (Sow.).

20.—[1617].—*Portlocki bed* is full of the beautiful astreiform corals in brown limestone, a section cut from any part is an equally good example.

Lithostrotion Portlocki (Edwds.); *Cyathophyllum regium* (Phill.), *turbinatum* (Sow.); *Michelinia tenuisepta* (Goldf.).

21.—[1620].—*Cyrtina bed* contains good specimens of *Cyrtina septosa* (Dav.); *Spirifera lineata* (Mart.).

[1849].—Here we come to the end of the quarry, and arrive at the new zigzag path from Clifton Down. At the top of this, on the Durdham Down side, may be taken good examples of *Phillipsia*, although not plentifully distributed. On the edge of Clifton Down, at the top of the road, is an interesting three inch black bed, which is only here exposed, which we name the

22.—*Bellerophon bed.* This limestone is noticeable for allowing the fossils to come away in a perfect state by a blow of the hammer, so that no occasion exists for carrying home a large piece of the matrix, as is usually unavoidable.

We now arrive at one of the great points of interest in the Clifton rocks, viz., the remains of a former coral reef. Throughout the next 1290 feet the rocks are entirely filled with the most lovely forms of Zoanthidœ, which, from their large size, must have thriven in the greatest luxuriance in the warm waters of the ancient carboniferous sea. Here may be seen tons of Cyathophyllidœ, three inches in diameter, and of proportionate length with the tiny *Alveolites* and *Syringopora*, surrounded with the washings of the waves and the entomostraca that usually inhabit such localities. Indeed, here may be exhibited the natural history found at the bottom of a tropical sea.

23.—[1859].—*Aulophyllum bed*, is a reddish brown limestone with

Aulophyllum fungites (Edwds.); *Clisiophyllum coniseptum* (Keys.) *Lithostrotion concinnum* (Edwds.); *Cyathophyllum regium* (Phill.).

24.—[1892.]—*Ellipsolithes bed* is a thin bed, and is the chief locality in which we can get.

Ellipsolithes compressus (McCoy.); *Euomphalus tuberculatus* (Thor.).

25.—[1897.]—*Vesicularis bed* is a good one for this variety of *Terebratula hastata*, of which it is probably the young.

26.—[1901].—*Chætetes bed* is the source of splendid examples of the *Chætetes radians*. They are very large, and the sections, when

polished, are exceedingly handsome. In the other beds the specimens are not nearly so fine.

Chætetes radians (Flem.); *Lithostrotion irregulare* (Edwds.).

27.—[1908].—*Comoides bed* is a black oolitic limestone, containing a great number of

Chonetes comoides (Fisch.); *Orthoceras Sp.?; Producta Cora* (D'Orb.); *Alveolites septosa* (Edwds.)

[1910].—Another bed, similar to the last.

28.—[1916].—*Zaphrentis bed* is a dark coloured limestone, with very fine examples of *Zaphrentis Griffithsi* (Edwds.); *Amplexus coralloides* (Sow.); *Conocardium giganteum* (McCoy.).

29.—[1944].—*Gigantea bed,* so called from the enormous specimens of Producta gigantea found in a dark oolitic limestone.

30.—[1946].—*Foraminifera bed* is a good example of the fossil bed of an ocean. It is almost entirely made up of small foraminifera shell-debris, echinus spines, &c.

31.—[1948].—*Irregulare bed* is a red limestone bed, very siliceous, and one mass of *Lithostrotion irregulare.*

32.—[1961].—A bed of limestone, containing very large specimens of *Euomphalus tuberculatus,* some of them being four inches in diameter.

33.—[1968].—*Coral beds.* These are the principal coral bearing beds of the section, and contain a greater part of all the known species occurring in the locality.

Cyathophyllum regium (Phill.), *Stutchburyi* (Edwds.), *Murchisoni* (Edwds.); *Lithostrotion ensifer* (Edwds.), *Martini* (Edwds.), *basaltiforme* (Edwds.), *junceum* (Edwds.), *Lonsdaleia floriformis* (Edwds.), *Aulophyllum fungites* (Edwds); *Alveolites depressa* (Edwds.); *Clisiophyllum coniseptum* (Keys).

34.—*Plant bed.* This is a dark coloured oolitic bed, containing coal plants, with a large number of *Lithostrotion irregulare.*

35.—Is a light brown limestone, with very fine masses of *Cyathophyllum regium.*

36.—*Stigmaria bed.*

37.—*Murchisonia bed.* This, though disturbed, is evidently a

continuation of the upper limestone series. It contains many univalves, which have, by many, been thought doubtful as Clifton specimens. It is a dark semi-crystalline limestone passing into one having a lighter colour. The fossils are very distinct from those found in previous beds.

Murchisonia angulata (Phill.); *Platyschisma tiara* (McCoy.), *Jamesoni* (McCoy.); *Naticopsis variata* (Phill.), *spirata* (McCoy.); *Loxonema rugifera* (Phill.); *Bellerophon apertus* (Sow.); *Conularia quadrisulcata* (Mill.); *Sedgwickia centralis* (McCoy.).

38.—*Orthoceras bed* contains weathered encrinites, and imperfect specimens of a large orthoceras.

39.—[2260].—*The Great Fault*, very properly so named, and is well worthy of a visit from every one studying the Clifton rocks. This spot bears most evident testimony to the great convulsive power that nature sometimes puts into action. Through the distance of 1090 feet, the ground is distorted and broken up in the utmost confusion, and the rocks twisted and overturned. The strata has been displaced to the extent of 800 feet vertically. One side upheaved, the other depressed and at the same time lateral pressure completed the destruction. Beds of coal mixed with millstone grit are side by side with mountain limestone, while the 500 feet of upper shales have been, as it were, buried out of sight, and the Avon gorge riven asunder. All these are open to the eye of the observer of the present day. So great was the disturbance of the country, that one half was turned one-fourth of the whole compass; the beds below the Great Fault dip to the S.S.E. 30°, while those above the Great Fault dip to the N.E. 70°. At the entrance to the tunnel, near the Clifton Station, coal beds may be seen, which have been buried 300 feet in the ground, while the same beds have, since that time, been entirely removed by denudation from the surface of the higher ground in the immediate neighbourhood. Complete evidence of lateral pressure may be seen by the curling of the marls and shales as they were forced against the massive beds of the St. Vincent's Rocks, which are only a repetition of the mountain limestone before described.

40.—A bed of gray limestone, containing *Terebratula hastata* (Sow.); *Syringopora geniculata* (Edw.).

41.—A bed of limestone, containing *Producta* and *Rhynchonella pugnus*.

42.—*Syringopora bed.*—A bed of limestone, containing the following corals. The last three beds are repetitions of those near No. 33.

Alveolites septosa (Edw.), *depressa* (Edw.); *Chætetes radians* (Flem.); *Syringopora reticulata* (Goldf.), *lamellosa* (Edwd.), *geniculata* (Edwd.); *Lithostrotion junceum* (Edwd.), *affinis* (Edwd.); *Ptylopora frustraformis* (Phill.).

Near this spot, and a few feet before the next mentioned bed, is the long-famed Hotwell Spring, the water of which issues at the rate of 60 gallons per minute, at a tolerably uniform temperature of 70° Fahr. When freshly drawn, it is full of bubbles of Carbonic Dioxide and Nitrogen Gases, of which the late Mr. Herapath estimated that each gallon contained nearly 16 cubic inches. According to that chemist, analysis shewed that the water contained.

Chloride of Magnesium - - - -	2·180
Nitrate of Magnesium - - - -	2·909
Chloride of Sodium - - - -	5 891
Sulphate of Sodium - - - -	3·017
Sulphate of Magnesium - - - -	1·267
Carbonate of Calcium - - - -	17·700
Carbonate of Magnesium - - - -	·660
Carbonate of Iron - - - -	·103
Bitumen - - - - - -	·150
Sulphate of Calcium - - - -	9·868
Silica - - - - - -	·270
Total solid contents per gallon -	44·015 grains

43.—[2675].—*Solenopsis bed.*—It is now difficult to examine because it is not worked. It contains, however, many small corals, bivalves and univalves The principal fossil is the *Solenopsis minor*, which is tolerably plentiful and in good preservation.

44.—*Rhynchonella bed.*—This is a good fossiliferous bed, behind the Colonnade, and crops out again near the south buttress of the Suspension Bridge. The specimens of *Producta* and *Euomphalus* are larger here than in any other part.

Rhynchonella pugnus ; Producta gigantea ; *Euomphalus tuberculatus* : *Sanguinolites angustata* ; *Myacites tumidus.*

45.—*Foraminifera bed.*—Although five good beds are known, yet this one is perhaps the best. It is oolitic in its structure, the granules being white, in a reddish brown matrix. It is impossible to cut a slide for the microscope without having three or four species of foraminifera on it. Almost every granule has for its nucleus a foraminifer or minute shell. Among others have been noticed the following genera—

Trochammina, Textularia, Climacammina, Stacheia, Endothyra, Lituola, Archædiscus, Valvulina, Nodosinella.

46.—Is a bed with abundance of *Terebratula hastata.*

47.—*Stutchburyi bed.* This is a very thick bed of brown limestone, full cf larged sized corals, sufficiently perfect for the observation of all their anatomical details.

Cyathophyllum Stutchburyi (Edwd.), *regium* (Phill.); *Campophyllum Murchisoni* (Edwd.) ; *Lonsdaleia floriformis* (Edwd.) ; *Lithostrotion Martini* (Edwd.), *carnea* (Edwd.) ; *McCoyanum* (Edwd.)

48.—*Convoluta bed* is a reddish sandy limestone, very full of fossils, among which are *Spirifera convoluta* or *rhomboidalis* (Phill.) ; *Cyrtina septosa* (Dav.) ; *Producta Martini* (Sow.), *longispinosa* (Sow.). *Pinna*, sp ? ; *Pecten*, sp ?; *Cochliodus contortus* (Ag.)

The five last beds are hidden by the houses, so that the examination must either be conducted by going through the gardens, or by finding them on the opposite side of the river.

On these lie the upper limestone shales, which are extremely sandy in their character, giving rise to the name of "Upper Grits." They are about 400 feet in thickness. They are not so rich in fossils as the other parts of the Clifton section, although 52 species have been noted.

[3045,]—This is the last of the Upper Shales, just below the

commencement of the Millstone Grit or farewell rock, the first bed of which may be seen behind the General Draper Inn. These beds are highly charged with Hematite. In some places the Ferric oxide is found as an amorphous deposit, containing from 40 to 50 per cent. of metallic iron. It is however, much mixed with silica, which consequently detracts from its value.

Perhaps a fair average of metallic iron would be about 30 per cent. Analyses of these Hematite ores from Clifton, Ashton, and Winford, chosen from the ordinary earthy samples, gave the following results.—

Ferric Oxide	75.19	72.00	85.00
Calcic Carbonate	3.54	2.16	1.01
Alumina	5.15	2.14	6.13
Silica	4.26	14.50	5.22
Manganese	trace	.21	.82
Phosphoric Acid	.01	.37	·25
Sulphur	.02	.03	trace
Moisture, &c.	11.83	8.59	1.57
	100.00	100.00	100.00
Metallic Iron	52.63	50.40	58.9

On the surfaces of some of the upper beds of siliceous limestone, or else enclosed in some of the larger crystals of quartz, are beautiful bright crystals of Hydrated Ferric Oxide (Göthite). On the beds near the southern buttress of the Suspension Bridge, are good specimens of Carbonate of Iron.

Good localities for collecting Carboniferous fossils are Cheddar, Portishead, Henbury, Weston, Clevedon, and many parts of the Mendip Hills.

The following is a list of the principal fossils that have been noticed in the Carboniferous rocks of the district.—

Felicites dichotoma
Knorria
Trochammina centrifuga (Brady)
incerta (D'Orb)
Archædiscus Karreri (Brady)
Textularia eximia (D'Eichwold)
Climacammina antiqua (Brady)
Stacheia pupoides (Brady)
Lituola Binnicana (Brady)
Nodosinella concinna (Brady)

Endothyra Bowmani (Phill.)
ammonoides (Brady)
globulus (D'Eich)
ornata (Brady)
tenuis (Brady)
obliqua (Brady)
radiata (Brady)
Valvulina decurrens (Brady)
palæotrochus (Ehr)
v. compressa
Alveolites depressa (Edwd.)
septosa (Edwd.)
Chœtetes radians (Flem.)
Michelinia tenuisepta (Goldf.)
Syringopora reticulata (Goldf.)
lamellosa (Phill.)
geniculata (Phill.)
Campophyllum Murchisoni (Edwd.)
Cyathophyllum regium (Phill.)
Stutchburyi (E. & H.)
Murchisoni (E. & H.)
turbinatum (Goldf.)
Lonsdaleia floriformis (E. & H.)
Zaphrentis Griffithsi (E. & H.)
Amplexus coralloides (Sow.)
Lithostrotion ensifer (E. & H.)
Martini do.
Portlocki do.
irregulare do.
basaltiforme do.
junceum do.
concinnum do.
affine do.
carnea do.
MacCoyanum (Edwd.)
Aulophyllum fungites (E. & H.)
Clisiophyllum coniseptum (Keys.)
Cyathocrinus planus (Mill.)
Dichochrinus radiatus (Aust.)

Poteriocrinus conicus (Phill.)
crassus (Mill.)
isacobus (Austin)
plicatus do.
pentangularis (Mill.)
tenuis do.
rostratus (Austin)
Rhodocrinus costatus do.
granulatus do.
verus (Mill.)
Synbathocrinus conicus (Phill.)
Platycrinus covonatus (Goldf.)
granulatus (Mill.)
levis do.
Platycrinus rugosus (Goldf.)
striatus (Mill.
triginta dactylus (Austin)
tuberculatus (Mill.)
Actinocrinus aculeatus (Austin)
amphora (Goldf.)
cataphractus (Austin.)
elephantinas (Austin)
lœvissimus (Austin)
triacontadactylus (Mill.)
Pentremites globosus (Sow.)
Palœchinus
Serpula omphalodes (Goldf.)
Ceratiocaris
Leperditia Okeni (Muenst sp.)
var subrecta
Cythere oralis (n. sp.)
Cytherella lunata (n. sp.)
Phillipsia pustulata (Schloth)
Brongniarti (Fisch)
seminifera (Phill.)
Ptylopora pluma (McCoy.)
flustraformis (Phill.)
Fenestella flabellata (Lonsd.)
irregularis (Phill.)

polyporata (Portl.)
membranacea (Lonsd.)
Retepora prisca (Lonsd.)
Ceriopora interporosa (Goldf.)
rhombifera do.
Terebratula hastata (Sow.)
var ficus (McCoy.)
sacculus (Mont.)
vesicularis (DeKon)
Rhynchonella acuminata (Sow.)
pleurodon (Fisch.)
pugnus (Mart.)
Camarophoria globulina (King)
Spirifera cuspidata (Mart.)
Mosquensis (Fisch.)
convoluta var rhomboidea (Phill.)
lineata (Mart.)
bisulcata (Sow.)
glabra (Mart)
duplicicosta (Phill.)
striata (Mart.)
var attenuata
Cyrtina septosa (Dav.)
Athyris Royssii (Dav.)
lamellosa (L'Eo.)
Retzia radialis (Phill.)
Streptorhynchus crenistria (Dav.)
var arachnoidea (Dalm.)
Orthis resupinata (Mart.)
Michelini (L'Eo.)
Strophomena analoga (Phill.)
Productus scabriculus (Mart.)
Cora (D'Orb.)
Martini (Sow.)
longispinus (Sow.)
punctatus (Mart.)
giganteus (Mart.)
pustulosus (Phill.)
Chonetes comoides (Fisch.)
Sordida (Sow.)

papilionacea (Phill)
Hardrensis var perlata (Phill)
Buchiana (DeKon.)
Discina nitida (Lam.)
Lingula mytiloides (Sow.)
Pecten sp. (Br. Mus.)
Avicula Damnoniensis (McCoy.)
Aviculopecten granosus (Phill.)
fallax (McCoy.)
Pinna sp ? (Br. Mus.)
Modiola sp ? do.
Macadami (McCoy.)
var elongata
Cucullœa trapezium (McCoy.)
Hardingii (Sow.)
Conocardium giganteum (McCoy.)
Cypricardia rhombea (P. Mus. G.)
parallela (Phill.)
Sanguinolites angustata (Phill.)
complanata do.
transversa (Portl.)
Venus sp ? (Br. Mus.)
Pullastra perforans
Sanguinolaria sulcata (Phill.)
Solenopsis minor (McCoy)
Corbula Hennahii (Sow.)
Myacites tumida (Phill.)
Sedgwickia centralis (McCoy.)
Edmondia quadrata (Röm.)
Conularia quadrisulcata (Mill.)
Murchisonia spirata (Gold.)
angulata (Phill.)
Pleurotomaria biserrata (Phill.)
pygmœa (Stodd.)
canalienlata (McCoy.)
Platyschisma tiara (McCoy.)
Jamesii do.
Euomphalus tuberculatus (Flem.)
acutus (Sow.)
Calyx (Phill.)
nodosus (Sow.)

pileopsideus (Phill.)
Dionysii (Goldf.)
triangulatus (Stodd.)
Loxonema rugifera (Phill.)
Capulus vetustus (Mondf.)
Natica plicistria (Phill.)
variata (Phill.)
elliptica (Phill.)
Naticopsis spirata (McCoy)
Bellerophon apertus (Sow.)
Discites compressus (McCoy.)
Nautilus biangulatus (Sow.)
dorsalis (Phill.)
Orthoceras cinctum (Sow.)
gregarium do.
Breynii (Mart.)
Cyrtoceras sp ?
Amblypterus Portlocki (Egert.)
Cladodus Milleri (Ag.)
mirabilis do.
conicus do.

Deltoptychius acutus do.
Tomodus convexus do.
Chomatodus cinctus do.
linearis do.
Cochliodus contortus do.
Ctenacanthus brevis do.
minor do.
Ctenacanthus tenuistriatus do.
Helodus gibberulus do.
lœvissimus do.
subteres do.
turgidus do.
Onchus hamatus do.
sulcatus do.
Orodus cinctus do.
ramosus do.
Oracanthus Milleri do.
minor do.
pustulosus do.
Psammodus porosus do.
rugosus do.

[redacted]

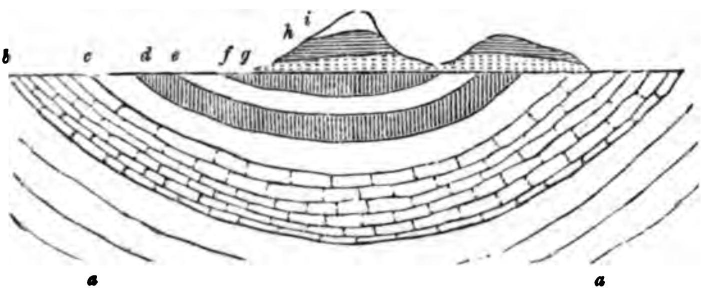
Geology of the Bristol Coal-field.

PART 4.—THE COAL MEASURES.

Read at the General Meeting, December 2nd, 1875.

WE now arrive at the most important of all our geological deposits—that useful mineral, Coal. Immediately upon the Upper Limestone shales we find a very thick deposit of Sandstones and beds of Coal of various thicknesses. They always appear in basin-shaped depressions, and in very regular layers, having a thickness of between 7000 and 8000 feet.

Fig. 18.—*Diagram of Bristol Coalfield.*



a Devonian—*b* Carboniferous Limestone—*c* Millstone Grit—*d* Lower Coal Measures—*e* Pennant Grit –*f* Upper Coal Measures—*g* Trias—*h* Lias—*i* Inferior Oolite.

On looking at our map, we find two or three of these Coal-basins near the surface of the ground, and some hidden from our view by several hundred feet of Triassic and Liassic strata. The longest of these is in Gloucestershire, twelve miles long and four wide. All over this field are extensive Collieries at Iron Acton, Coalpit-heath, Kingswood, Mangotsfield, and Fishponds.

Another Coalfield is on the south side of Dundry, about six miles in length and two in width, furnishing material at Pensford, Clutton, Paulton, Radstock, &c. A third division is that of Bedminster and Ashton, all of it being covered by the Lias.

A small Coal-basin is at Nailsea. It was formerly supposed to be merely a continuation of the Bedminster beds, but an examination of the surrounding Limestone is against this idea On every side the Limestone dips towards the centre of the basin, except on the west, where all the Limestone has been washed away by the waves of the sea. The deposit is small—only about three miles by one and a half. Here the Coal is worked both in the Pennant and Lower measures.

The borings and sinkings for the Severn Tunnel, prove that the Coal beds and Pennant grits extend under the Severn into Monmouthshire. Some thin seams of good Coal were extracted when making the shaft at Portskewet, containing numerous specimens of fossil ferns.

The entire Coal series may be well divided into four distinct parts, each lying within the other, and all in a basin-shaped cavity. The first being deposited immediately on the upper shales of the Carboniferous Limestone.

1.	Millstone Grit. ...	1000	feet in thickness.
2.	Lower Coal Measures	2000	,,
3.	Pennant Sandstone ...	1725	,,
4.	Upper Coal Measures...	3000	,,
		7725	

MILLSTONE GRIT.

The close of the Carboniferous period was marked by the surface of the land gradually rising, and a sandy deposit, formed by the disintegration of the Devonian rocks, so that the upper shales are easily distinguishable from the aluminous shales at the base of the Carboniferous rocks.

The Millstone Grit follows so gradually and conformably that it and the shales are sometimes undistinguishable. Generally speaking, the Millstone Grit beds are very thick and solid, as may be seen on the slopes of Brandon and Clifton hills. The Grit is formed of the hardest crystalline grains of sand, agglomerated with oxide of iron. In some places the iron is so abundant that the colour is a dark red, while in others it is a delicate pinkish grey. Some specimens are homogeneous, others are prettily striated. So hard are some beds, that they are preferred to Welsh Greenstone for paving stones where the traffic is heavy. Frequently the Devonian Mica is plainly visible. Sometimes a large percentage of limestone is met with, and most probably owes its presence to the shells of bivalves. In one of the lower Brandon-hill beds a large number of *Productæ* are seen, where the lime has totally disappeared, having been dissolved out, leaving a hollow cast of the shells. The Millstone Grit is not generally very fossiliferous, only a few beds in this neighbourhood being productive. Major Austin was fortunate enough to find a large number of mollusca and fish remains in one of the Tyndall Park beds, whence he obtained upwards of forty species. The only other localities that I have found to be fossiliferous have been on the north and south sides of the Avon, near Rownham ferry, the base of Brandon-hill, and near the fault in Leigh Woods.

The thickness of the Millstone Grit in this neighbourhood has been variously estimated. Mr. Etheridge puts it as 1200 feet, Mr. Anstie at 1000 feet, Professor Hull at 950 feet, while Major Austin estimates it at more than 2000 feet. From my own observations, I think 1000 feet is not far from the truth. However this may be, the Millstone Grit must have taken a very long period for its deposition. The regularity of the bedding, and the variation in the petrology and the occasional bands of limestone prove this. In the Millstone Grit are one or two seams of Coal, but quite unworkable.

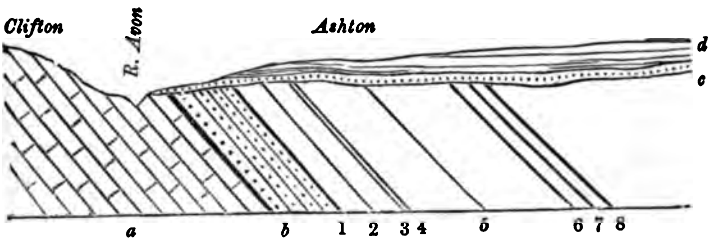
The Lower Coal Measures.

The Coal-bearing strata of this neighbourhood are divided into two sets, by an intervening band of grits called Pennant. The

Lower Coal Measures have an average thickness of 2000 feet; they lie an enormous depth from the surface, and can only be reached where they crop up. This will be at once evident by an examination of the diagrams. This remark is especially referable to the lowest seams. The principal collieries working this division of the Coal measures, are at Yate, Pucklechurch, Wapley, Cromhall, the north side of Kingswood, Fishponds, St. George's, Bedminster, Ashton, Nailsea, Holcombe, Vobster, and Ashwick.

At Bedminster the seam may be conveniently divided into two groups, the Bedminster and Ashton, the latter underlying the former.

Fig. 19.—*Bedminster Coal-field.*

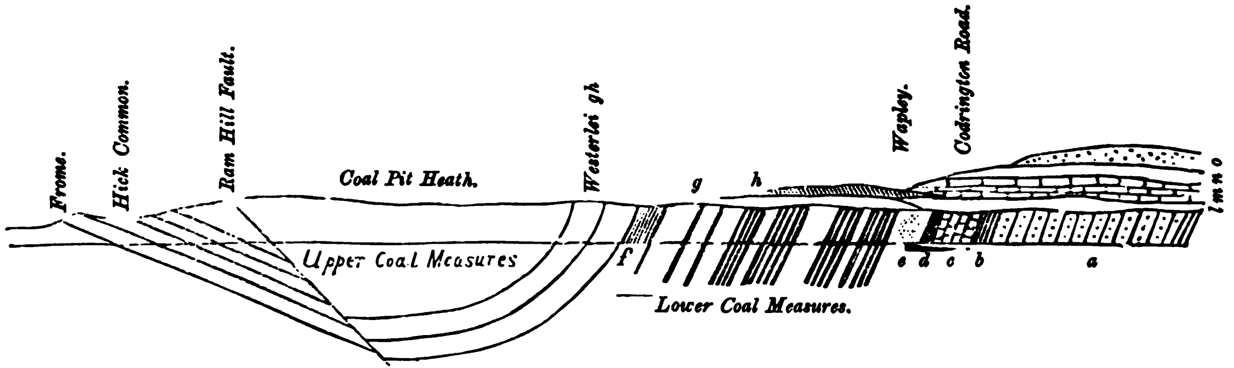


a Carboniferous Limestone—*b* Millstone Grit—*c* Magnesian Conglomerate—*d* Keuper

1. Little Vein.
2. Great Vein.
3. Top Vein.
4. Smith's Vein.
5. Toad Vein.
6. Bedminster Little Vein.
7. Bedminster Great Vein.
8. Bedminster Top Vein.

At Kingswood the lower Coal measures would not be workable if they had not been brought near the surface by a considerable upthrow, forming an anticlinal running in a S.W. direction from the West of Wick to the South of Fishponds. Till lately we supposed that all the possible seams had been reached, and that the Millstone Grit, or farewell rock appeared at Kingswood and of course prevented any possibility of going lower. However Mr. Cossham has proved that the supposed Millstone Grit is Pennant Sandstone that lies above instead of below the lower seams. The result is, that there remains a very extensive amount of Coal yet to be reached.

Fig. 20.—*Diagram of the Gloucestershire Coal-basin.*



a Devonian.—*b* Lower Limestone Shales.—*c* Carboniferous Limestone.—*d* Upper Shales.—*e* Millstone Grit.—*f* Pennant dividing Lower from Upper Coal Measures.—*g* Keuper.—*h* Rhætic.—*l* Lias.—*m* Marlstone.—*n* Upper Lias.—*o* Lias Sands.

Thirty-six seams of Coal are worked in the lower Coal measures. Westward of Cromhall the beds are entirely covered over by the new red. Here the upper Coal seam is 411 feet from the surface. At Kingswood the seams are very irregular from numerous faults and often rolled. In making the tunnel under the Severn the beds of shale and coal were found to be frequently upheaved from these undulations. At Bedminster and Ashton the seams come comparatively close to the surface. At Bedminster the first Coal seam is reached at 174 feet, and at Ashton at 270 feet. The Gloucestershire Coal-basin terminates here, being separated by an anticlinal limestone ridge, from a smaller basin at Nailsea. The probable thickness of the Nailsea Coal measures is about 1350 feet. The Coal unfortunately is very poor and sulphureous, and this, with an enormous influx of water, will, it is feared, stop any Coal mining in this basin.

South of the Mendip range, coal has been found, but the seams appear to have suffered from the violent disturbance which raised those hills and are "faulted" to a very large extent. Many of the seams give off fire damp. It is particularly troublesome at the Edford collieries. Here the disturbance has been so great, that the seams are nearly vertical. This is so at the Barton collieries also.

Mr. Anstie thinks, with great probability, that these now separate coal-fields were once continuous.

When the shaft at Portskewet for the tunnel was made, several thin seams of Coal from the lower measures were passed with very hard firestone. The coal was full of fragments of ferns.

As a rule, the Lower Coal Measures furnish a short list of plants whose names have been determined, but, probably, this entirely arises from want of a proper examination. Those that have been identified as having found in the lower seams, are so marked in the list of fossils at the end of this section.

PENNANT SANDSTONE.

Upon the last of the Lower Coal Measure series, lies a mass of sandstone rocks 1725 feet thick. The Pennant grit is peculiar to

our district, and is so similar to the coal shales, that the absolute division cannot always be positively stated. The beds are not visible in the southern portion of the coal-field, but come to the surface and afford excellent opportunities for inspection at Crew's Hole, Hanham, Stapleton, and Winterbourne. In the railway cutting at Mangotsfield station, an especially good section may be seen, containing traces of Coal. Between Mangotsfield and Winterbourne two seams of Coal have been worked.

Three of the Kingswood seams may almost be regarded as belonging to the Pennant.

At Stapleton, many fine specimens of trees have been found. A year or two ago the trunk of a Sigillaria elongata (Brong.) was exposed, 30 feet long, with both ends buried, so that the total length must have been great. The pennant is extensively quarried for building purposes, especially where large slabs are required. The steps in front of the Museum are Pennant, and are full of fossil wood.

At Nailsea the Pennant thins out, the total thickness being only about 450 feet. There a seam of Coal 3 feet thick occurs near the Church.

Pennant Sandstone often so nearly resembles Millstone Grit in its composition and structure, that it is quite impossible to distinguish them.

Five seams of Coal have been worked in the Pennant series, giving 10 feet of Coal.

In the Pennant, the following fossil plants have been collected.—

Halonia irregularis (Lindl.)
Ulodendron minus (Broug.)
majus (E. & H.)
Knorria intricata (Sternb.)
Calamites approximatus (Broug.)
arenaceus do.
cannœformis (Schl.)
Suckovii (Broug.)
Sigillaria elongata do.
ornata do.

Dadoxylon approximatum (Williams)

Upper Coal Measures.

We now come to the highest and last portion of the Coal Measures. Owing to their being so near the surface many of the seams have been washed away. They may be examined at Coal-pit Heath, Parkfield, Westerleigh, Radstock, and Farringdon.

The Coal from the workable seams in Gloucestershire is of very good quality, some being highly bituminous. They are well adapted for gas and steam purposes.

From Brislington, southwards, the Coal measures are covered up completely by the New Red Marls, Lias, and inferior Oolite; after passing under Dundry Hill they emerge and come nearer the surface. At Clandown the shaft commences at the junction of inferior Oolite with the Upper Lias, and reaches the "Great" seam at the depth of 1212 feet. At Radstock the beds of Coal are thin, and necessitate the removal of an immense mass of useless shale.

The Upper Coal Measures have a total thickness of 3000 feet, and contain 22 workable seams of Coal with an aggregate thickness of 18 feet.

The Upper Coal Measures afford the most abundant supply of fossil plants, especially ferns. They are obtained from the shales overlying the Coal.

The following are the depths from the surface, to which shafts have to be sunk before reaching the first workable seam of Coal.

Easton	94	feet.	Malago	210	feet.
Kingswood	183	,,	Nailsea	330	,,
Newton St. Loe	300	,,	Parkfield	543	,,
Twerton	360	,,	Clandown	1212	,,
Ashton	270	,,	Camerton	690	,,
Bedminster	174	,,	Paulton	348	,,
Wapley	300	,,	Farringdon	198	,,

The faults are very numerous, and some of them very deep. They penetrate in every direction, and in various ways. The strata appear not only to have been severed by a down or up throw, but

also subjected to enormous *side* pressure, for the Coal Measures in many places, as for instance from Patchway to Portskewet, assume the most extraordinary contortions and wave-like forms. The subterranean force that produced this, most probably happened when the Clifton chasm appeared. The great Avon fault shews great diagono-lateral pressure, and twisting the strike of the beds from N.E. and S.W. to N.W and S.E., thus turning the dip of the beds nearly a fourth of the compass.

A singular bed of Conglomerate 60 feet in thickness, intervenes between the "Polecat" and "Doxall" veins. It is composed of water-worn flint and other pebbles, and is cemented together with carbonate of lime. Among these pebbles are some curious light green ones, the exact nature of which is not quite clear. The most curious part of it is, that the very same kind of conglomerate occurs in the Worcestershire and Shropshire coal-fields. In each place the peculiar green pebbles occur, and the whole conglomerate is so closely alike, that it is quite impossible to distinguish the several specimens. A hard strong bed lies between this conglomerate and the "Doxall" seam, forming a good roof.

Formation of Coal.

The microscopical and chemical examination of the several varieties of Coal shew most conclusively that it had a vegetable origin, and that it is the result of slow decomposition. That the trees grew where we find them is evident because on opening a Coal seam we find them in situ with the roots penetrating the ground in every direction.

In many places at the present day we find the counterpart of the old coal forest.

The well known Fern Creek at Dandenong in Australia is in a hollow and it generally happens in sub-tropical climes that these beautiful cryptogams prefer sheltered cavities where the decadent leaves falling from the stem, leaving the "scar," and perish on the damp ground; and all our carboniferous Coalfields are in the form of a series of hollows.

It is certain therefore that where we now find the Coal, was once a magnificent forest of Conifers and Treeferns 50 or 60 feet high, with a dense undergrowth of gigantic club mosses, growing in a dark and muddy swamp near the sea, and subject to an influx of the waves at high tides.

When a tree therefore was destroyed instead of lying exposed to the atmosphere and suffering the usual decomposition, it was at once buried in the mud and sand.

At the close of the carboniferous shales, as we before stated, the land was gradually rising, and after a very long period had passed, and sand had accumulated to the thickness of the millstone grit, a hollow creek appeared formed by a sluggish river, causing a kind of estuary. On this spot grew the rich growth of trees to which allusion has been made. After many years of luxuriance the land subsided a few feet and allowed the mud and sand to cover up the ground and destroy the vegetation. The leaves and broken bits of wood ground to pieces by the force of the water, got mixed with the sand, just as we now find them. The land again rose and and another forest was the result, which in its turn became engulfed. This is believed to be the explanation of the formation of the alternating beds of Coal and clays.

We always find that every Coal seam reposes on a bed of under clay. The Coal seam represents the vegetation while the under clay was the actual soil in which the plants grew. What was once a soft, oozy mud has been hardened by the lapse of ages, till now it is a hard stone and used for making the best firebrick.

After these changes had gone on for a long period of time, a great silting up with sand took place, forming what we know as the pennant sandstone. After a long continuance of sandy waste and another change of level, a second series of forests made their appearance in like manner until they in their turn were buried, in order to form a future storehouse of fuel beneath the conglomerates and sandstones of the Trias.

Coal is formed from slow oxidation of wood or cellulose aided by warmth and moisture, and the consequent evolution of marsh gas

and carbonic acid, till practically nothing but carbon is left as in Anthracite; when this change has only partially taken place then we have *lignite*. The production of Coal from woody fibre, may be explained in four ways, either separately or all at the same time, the oxidation being varied under different circumstances.

1. By decomposition as Carbonic Acid and Water.
2. Do. do and Marsh Gas.
3. Do. Marsh Gas and Water.
4. Do. Carbonic Acid, Marsh Gas and Water.

The latter being the most probable. The production of two of our Coals from woody fibre, may be represented by the following formulæ—

NAILSEA COAL.

$$\underset{\text{Cellulose}}{6\,C_6H_{10}O_5} + \underset{\text{Oxygen}}{6\,O_2} = \underset{\text{Coal}}{C_{22}H_{18}O} + \underset{\text{Marsh Gas}}{2\,CH_4} + \underset{\text{Carbonic Acid}}{12\,CO_2} + \underset{\text{Water}}{17\,HO_2}$$

RADSTOCK COAL.

$$\underset{\text{Cellulose}}{6\,C_6H_{10}O_5} + \underset{\text{Oxygen}}{2\,O_2} = \underset{\text{Coal}}{C_{26}H_{20}O_2} + \underset{\text{Marsh Gas}}{2\,CH_4} + \underset{\text{Carbonic Acid}}{8\,CO_2} + \underset{\text{Water}}{16\,HO_2}$$

When wood has decayed, a small quantity of Humus is generally formed which has the peculiar property of absorbing Ammonia, and it is thus that the occurrence of Nitrogen in Coal is explained, The Sulphur exists as Iron-pyrites or Gypsum.

The following are analyses of a few specimens of Coal from the Gloucestershire and Somersetshire seams.

	Sp. Gr.	Carb.	Hyd.	Oxy.	Nit.	Sulph.	Ash.	Water.
Great Vein...	1.30	84·46	5·17	3·03	1·01	1·16	3·67	1·50
Little Toad Vein	1·34	78·23	4·63	3.21	1·12	1·80	9·59	1·43
Upper 5 Coals	1·31	80·44	5·19	4·73	1·02	1·47	5·24	1·93
Coalpit Heath	1·31	83·28	5·17	3·04	1·16	·93	6·42	—
Holly Bush	1·33	74·24	5·68	6 16	·92	1·46	8 06	3·48
High Seam...	1·31	78·72	5·42	4·59	1·27	1·07	6·92	2·01
Top Vein	1·30	79·99	5·77	5·85	1·22	1·08	4·08	2·01
Hard Vein	1·29	81·29	5·77	4·99	1·34	1·62	2·88	2·11
Toad Vein	1·29	80·99	5·31	4·27	1·18	1·24	5·38	1·63
Lower 5 Coals	1·34	80·33	5·68	3·07	1·44	1·31	7·14	1·18
Thurfer Vein	1·30	85·97	3·68	3·23	·82	1·83	3·46	1·01
Nailsea	1·31	81·21	5·81	4·98	1·04	2·85	3·00	1·11
Radstock	1·28	79·37	6·37	5·46	1·12	3·10	3·50	1·08

The above elements combine to form two classes of Hydrocarbons, one volatile and the other not·

A good gas Coal has a large proportion of volatile Hydrocarbon, while a good steam Coal has a large proportion of solid Carbon.

For example, the following are the natural arrangement in some of the samples mentioned in the foregoing table, and copied from Messrs. Cossham and Co.'s paper read at the British Association

Great Vein (Kingswood) a good Steam Coal—

Fixed Carbon ...	70·84
Volatile Matter ...	21·62
Ash	5·84
Water	1·50
	100·00

Hollybush Vein (a good Gas Coal)—

Fixed Carbon ...	59·10
Volatile Matter ..	34·97
Ash and Water ...	5·93
	100·00

When pure Coal is burnt the ash only contains a minute portion of Alkaline salts. The greatest part consists of Calcium, Magnesium, Aluminium, Iron, and Silica, most likely introduced with the coal by infiltration of water. As may easily be supposed the Coal in different parts of the same seam varies considerably, in one place burning freely and leaving little ash, while in another the percentage of mineral matter is so great that "slates" are produced which, when placed in an ordinary fire, explode and fly all over the room. These originate from the mud present in the original water in which the plants grew.

The formation of the Coal measures must have taken an enormous time, as the transition from wood to coal was necessarily very gradual and slow. An immense number of ages must have elapsed since the life and growth of the tree, and the product we now use, and upon which we so greatly depend.

Professor MacLaren (Geol. of Fife, 116,) calculates that it would require 1000 years to deposit sufficient material for a bed of Coal one yard thick. Now our Bristol Coal-measures without the Millstone Grit, have a thickness of 6725 feet of which only 100 feet are seams of Coal, the rest being sedimentary material which Professor MacLaren calculates was deposited at the rate of two feet per century.

It would follow from this that the Coal would take (100 or $33\frac{1}{3}$ yards $\times$ 1000,) 33,333 years and 6725—100 $=$ 6625 feet and $\frac{6625 \times 100}{2} + 33{,}333 = 364{,}583$ years for the deposition of the whole Coal measures from the Millstone Grit upwards.

ESTIMATED THICKNESS OF THE COALFIELD.

Millstone Grit - - -	1000	feet.				
Lower Coal measures -	2000	with	36	seams of Coal	72	feet thick.
Pennant Grit - - -	1725	,,	5	,, ,,	10	,,
Upper Coal measure -	3000	,,	22	,, ,,	18	,,
	7725		63		100	

The quantity of Coal waiting for extraction is very large, Mr. Prestwich (Report Vol. 1. p. 50,) gives the following estimate of the future resources of the Bristol Coalfield, which was confirmed by Mr. Cossham at the last meeting of the British Association.

Quantity of Coal at a less depth than 1500 feet	= 1,718,791,280	tons
do. at a depth between 1500 & 3000 ,,	= 1,519,997,981	,,
do. do. do. 3000 & 6000 ,,	= 2,227,531,577	,,
do. do. do. 6000 & 8000 ,,	= 637,990,144	,,
	Total—6,104,310,982	tons

Now as Mr. Hunt says (Min. Stat. 1869,) that our annual output from 34 Collieries is 1,000,000 tons, it follows that our Coal supply is sufficient to last us 6000 years! In most specimens of our ordinary bituminous coal the vegetable structure is with

difficulty examined by the microscope. Nothing but a black powdery mass of Carbon is seen which is perfectly opaque, so that the observer is greatly discouraged with his attempts to discover the woody fibre, medullary rays &c., so clearly described in all microscopical works.

It is only now and then that a good solid piece is found, that it is possible to satisfactorily make out the vegetable structure by section. The most successful way to proceed, that I have met with, is to soak a piece of the Coal for a week or two, in a tolerably strong solution of Potassium Carbonate (Pearlash,) then after washing well in distilled water, to gently warm the specimens in strong nitric acid till they change to a resinous brown color. They must then be sliced with a thin sharp knife and then be mounted in Canada balsam. On an examination of one of these sections, three kinds of substances will be seen—an opaque black carbon scarcely showing any structure, earthy matter slightly coloured, and a yellowish red semi-transparent portion shewing the medullary rays and fibres in the most beautiful manner. It is from this last ingredient that the gas is produced, so that the greater per centage of this there is in a sample of Coal, the more advantageous is its use for gas works.

The fossils that have been noticed in the Bristol Coal measures are Conifers, Ferns and Club mosses. The author has not met with a single mollusc or animal remains of any description except in the Millstone Grit, this is probably owing to want of opportunity for observation, as it is not likely so large an area of swamp as the original forest must have been, should have had no aquatic animals.

In the early part of this year Count Castracane of Rome, reported to Mr. Sorby that he had discovered Diatomaceæ in English Coal ashes. Mr. Sorby reports he had seen on these slides several well preserved species of Diatoms and also bodies like Xanthidia. I have searched most diligently the Coal ashes of our Coal field but quite unsuccessfully. The Count's Coal was shipped from Liverpool.

The "roofs" over the seams are the localities which furnish many and beautiful varieties of the fern fronds. Some are ver productive, as for instance the roof of the "Hard seam."

The following list of fossils, although imperfect, yet contains a that have been well ascertained to have been collected from th Coal seams of the Bristol District.

Alethopteris Serlii (Brong.)
lonchitica (Sternb.)*
Mantelli (Brong.)
Caulopteris Phillipsii (Lind.)
primœva do.
Sphenopteris irregularis (Brong.)*
adiantoides do.
artemisiœfolia do.
Neuropteris acutifolia do.
acuminata do.
angustifolia do.
crenulata do.
flexuosa (Sternb.)
macrophylla (Brong.)
oblongata (Sternb.)
heterophylla (Brong.)*
Pecopteris abbreviata do.
oreopteridis (Schloth.)*
arborescens (Brong.)
aspidioides do.
Bucklandi do.
Cistii (Brown)*
Meriani (Brong.)
plumosa do.
cyathea do.
crenulata do.
Miltoni do. *
dentata (Brown)
pteroides (Brong.)
villosa do.
æqualis do. *
Aspidiaria anglica (Presl.)

Aspidiaria confluens (Presl.)
Lepidophloios laricinum (Sternb.)
Ulodendron minus (Brong.)
majus (L. & H.)
Conybeari (Smith)
punctatum (L. & H.)
Carpolithes alata
Calamites approximatus (Brong.)
undulatus (Brong.)
cannæformis (Schl.)
Suckovii (Brong.)
Cistii do.
Annularia fertilis (Sternb.)
longifolia (Brong.)
equisetifolia (Schloth.)
Calamocladus equisetiformis do.
Hippurites longifolius (Lind.)
Sphenophyllum emarginatum (Brong
fimbriatum do.
Schlotheimii do.
Sigillaria elegans do.
levigata do.
elongata do.
mammillaris do.
ornata do.
flexuosa do.
reniformis do.
scutellata do.*
tesselata (Sternb.)
Dadoxylon approximatum (Williams)
Lepidostrobus lepidophyllaceus(L.&H.
Trignocarpum Dawsii do.

* Found in Lower Measures.

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On Professor Renevier's Geological Nomenclature and Table of Sedimentary Rocks.

BY E. B. TAWNEY, F.G.S.

Read at the General Meeting, April 1st, 1875.

THE object of these notes is to bring before the Society Professor Renevier's Table of Sedimentary Rocks, which, though printed in French, will be found, I think, of great use even to English students. In the first place, it forms a most convenient guide to refer to if one is seeking the place among English strata, or the equivalence of any foreign beds; and besides, it gives in a very compact form the leading fossils of the various divisions of sedimentary rocks. This it effects most conveniently from being printed in diagram form with parallel columns; *e.g.*, if we refer to the Carboniferous rocks we find, besides the column of leading fossils, &c , nine columns which give information on the presence or absence of the different sub-divisions of the Carboniferous epoch and peculiarities of local facies, with the local names used in those nine districts. In the case cited, the nine are—(i) England, (ii.) France and Belgium, (iii.) Germany, (iv.) Russia, (v.) North America, (vi.) Jura Mountains, (vii.) Italian Alps, (viii.) Western Alps, (ix.) Eastern Alps.

In glancing through this scheme of the well-known Professor of Geology in the Lausanne Academy, we cannot do better perhaps than follow the order of his own remarks in the explanation which he has printed in his native language. To begin with then, we must note that the diagram is printed in horizontal bands of

different colours. There are nine of these bands, corresponding with the chief periods into which he divides the geological scale. These are the colours used by the Swiss Geological Commission, which is a body charged by the Federal Government with the execution of the geological map of Switzerland; and, therefore, as the table is designed, of course, primarily for his own countrymen, the compiler could not have done better than adopt the colours of the national map. Now Professor Renevier is one of the workers of the Federal survey and has just finished a sheet of part of the Western Alps, which will be a great boon to the visitors to the Bex Diablerets and Gruyere districts. He very justly remarks, therefore, that keeping the same conventional colours for both will much conduce to the rapid understanding of the maps. But he is perhaps a little sanguine in thinking that these colours are likely to be adopted by other nations. Of course, as the colours have been settled upon by the Federal Commission after, no doubt, mature consideration, we cannot presume to criticize them. Most of the colours of the English Geological Survey are, I think, admirably chosen, indicating very often the colour of the chief groups of beds themselves; *e.g.*, the Cretaceous with us is represented by various shades of green; it includes a great thickness of Greensand, and the Gault clay, which is a greenish blue; so are some of the Wealden beds. The Oolites are on our maps tinted yellow in different shades: this is the prevailing colour of the jurassic limestones with us. The Trias has a red colour, and very aptly for that is the chief tint of our New Red Sandstone and Bunter. The Coal Measures we represent by a diluted black; the Carboniferous Limestone is coloured bright blue, but this gives rise to little inconvenience in practice, though *a* blue (a different shade, however) is used by Limestone in the Silurians; and absolute regularity of shades is impossible, and very seldom do all the formations occur in the same sheet. The Old Red Sandstone has a darker shade of red. The Silurians are indicated by different shades of slate colour, the idea no doubt being taken from the colour of N. Wales roofing slates, the best slates coming chiefly from these older Palæozoic rocks.

It so happens that the Carboniferous rocks are the oldest known in Switzerland; there is, therefore, no colour settled by the Federal Commission for Silurian and Cambrian, &c., rocks. Professor Renevier has, therefore, had to chose one, and he has represented them by a pale crimson, which is used on their map for the crystalline schists and gneiss, his idea being that these may partly represent the missing older Palæozoic rocks.

So much for the conventional colours for geological maps, and for the significance of the coloured bands of which the diagram is composed. We must pay attention now to what the Professor calls the Hierarchy of the sub-divisions, for of this he makes rather a cardinal point. By this term is meant the different values given to words which denote divisions and sub-divisions, and so on. It is remarked, in zoology and botany there is a hierarchy of terms which are not allowed to be transposed; *e.g.*, Kingdom is a larger group than class, this than order, below which come family, genus, species: all these must be used in the proper order:—thus, an Order cannot be divided into classes,—the less into the greater; the word sub-order must be used if a sub-division is required. The rank of these words is universal and fixed in the sciences mentioned, but, as pointed out, is not so in geology. The words system, stage, group, or era, period, epoch, have quite different ranks attached to them by different authors; some divide a system into stages, others stages or formations into systems, and so on. It is held that this is very anomalous and should be rectified. Professor Renevier suggests that a set of words should be agreed upon which should everywhere, in geological use, have the same value. To begin with, he regrets as hierarchical terms the word *formation* (and in French the word *terrain*, also to which we have no exact equivalent in English) the former word being reserved to signify mode of formation; *e.g.*, marine, estuarine, &c. This is certainly to use the word in a more accurate way, and no doubt it would be well to follow his suggestion. We are, however, rather short of words to be applied to a mass of strata, and should be almost confined to the word *system*.

The hierarchical terms which the Professor proposes and uses in his table are these—

1.—Era ....e.g., Tertiary or Cænozoic.
2.—Period .... „ Nummulite.
3.—Epoch or System............ „ Sub-apennine.
4.—Age or stage, horizon ...... „ Astien

These words before they are generally adopted in a quasi-technical sense will of course be subjected to criticism; and we may venture to remark that there seems not quite enough difference in meaning between the words of the first column, which express the chronological point of view. We may suggest the word "Æon" as perhaps likely to be useful. Our terminology will still be defective because we have no words to express the former two divisions from a petrographical point of view. With respect to the word "system," we throughly approve of the place which is here given to it. Its connection with the Silurian epoch through the classical work of Murchison would compel us in England to restrict it to divisions of this rank and value. Professor Renevier remarks that in giving the word this valuc he has had to dethrone the "*étages*" of D'Orbigny, and make them take the lower place. Mr. K. Mayer also does the same. It would certainly be an improvement if geologists would follow our author's suggestion, and agree upon a definite hierarchy of words.

With respect to the nomenclature of the various sub-divisions and groups, Professor Renevier says that he has innovated as little as possible by usually adopting terms hitherto in use: even the words "gault" and "culm" are used, though they are incapable of taking the French adjective termination, and so agreeing with most of the other designations. The words "Keuper," "Ludlow," and "Caradoc," as applied to show a certain age of rocks, will be easily recognised in their French dress. Other examples of words which Professor Renevier has coined, though he deprecates their being called innovations, are "Gryphitien" for *Gryphæa arcuata* beds, "Opalinien" for *Amm. opalinus* beds. That he is no purist, is shown by his spelling the word Ludlowien, which stands for the

Ludlow rocks. The only two in the table which he admits to be entirely new, are those which he has introduced for the sub-divisions of the Permian, viz., "Thuringien" and "Lodevien:" the German terms "Zechstein" and "Rothliegende" are certainly very awkward.

The table contains all the synonyms or local names for the groups and divisions used in the different countries; they will be found in the columns under the heading of the country where they are used. This makes the table a most handy work of reference; suppose *e.g.*, that we wish to know the equivalent of the Werfen beds, we have only to glance down the column of the Alps till we come to them, and looking horizontally across the columns we see this equivalent in the different countries,—thus they correspond to the base of the Muschelkalk and are above the Bunter Sandstone.

In the Palæontological column the chief fossils of each group are given, and notes on the appearance and extinction of types of animals are added, *e.g.* the range of trilobites—the first appearance of Brachyurous Crustaceans, &c., may be here learned.

In the table here printed I have ventured to make an extraction from Prof. Renevier's table, taking therefrom the columns containing his terms, as well as Sir C. Lyell's grouping which is added for comparison. In the latter, however, I have made a few alterations, to bring it into accordance with later editions of Lyell's "Elements."

We may notice that the three great divisions or eras of column No. 1 agree with those of English, and I suppose most geological classifications for they are extremely natural: the change in life between the Palæozoic, Mesozoic, and Cenozoic is most distinctly marked. When we pass to column No. 2 of the rank of "periods," we find a divergence.

The first period "Anthropique" corresponds to the Quaternary of some authors; but Prof. R. rejects this word as this period is by no means equivalent to the Tertiary era, and there is no new flora and fauna; every one will agree in this, and we may be thankful to him for the term which signifies that the chief fact and interest in the period is the presence of man or his works. We miss the

familiar Pliocene and Meiocene which are terms of less value than those used by Prof. Renevier in this column : they are both included in the period "Molassique." The Eocene shades off so through the Oligocene into the Meiocene that it is impossible to draw hard lines between them, and therefore the grouping of this column may perhaps not be approved entirely. The next point in column No. 2 that we have to notice is the erection of the Lias into a period of the same rank as the Jurassic, and of a higher value than the Rhætic which is included in it. This is a great improvement on some classifications. Even in that of Prof. Morris and R. Jones* we notice that the Rhætic is made equivalent to the Lias : this seems to us very unfortunate, as in England these beds are not one tenth the thickness of the Lias, and are, palœontologically, mere passage beds between the Keuper and Lias—they may be placed under either of them, but are certainly equivalent to neither.

Below, in the column, we come to a period termed "Carbonique" which includes the Permian, Carboniferous, and Devonian: we are more accustomed here to the use of "Upper Palœozoic,"—a grouping which English authors will probably continue to use, though it does not follow that Carbonic is too like Carboniferous, or apt to promote misconception. One might even, perhaps, coin a word from some of the more common fossils of the period, such as *Sigillaria*, *Lepidodendron* or *Producta*. Perhaps more will be inclined to make objection to the period below, which is termed "Silurique :" we should almost like to restrict this word to the rank given it by Sedgwick or Lyell and other English authors who make it equivalent to, instead of including Cambrian. We shall prefer to use Lower Palœozoic to include this and the Laurentian, or as an equivalent to the professor's term, we might coin the word "Graptolitien" from a frequent fossil.

In glancing at the main groups of the first two columns we have deviated from the order of Prof. Renevier's explanation of the table, but for the remaining remarks we will read the table horizontally and so follow his text.

* Synopsis of Lectures on Geology, 1870 (Van Voorst), by Professors Morris and T. Rupert Jones.

To return to the sub-divisions of the Tertiaries, the smaller of the Sub-apennine or Pleiocene epoch are taken from the names of places in Italy with rich fauna, showing different ages. The Œningen beds have, generally, been accounted U. Meiocene. Prof. R. remarks that his two periods in the Tertiary correspond with the Upper and Lower Tertiaries of Karl Mayer who is undoubtedly a great authority: still these two divisions are not separated by a hard line. If the geological record was complete there would perhaps be no lines to be drawn at all except conventional ones. In the L. Tertiary we find our London and Barton clays and Thanetsands giving names to three sub-divisions.

Professor R. has not divided the Cretaceous into Upper and Lower, though he admits it might be replaced by two periods; it has however been so divided by Lyell in later editions that the one cited and by other English authors. Remarks are made on the different values given to the Neocomien group; Professor R. uses the word in the more restricted sense and separates from it the Aptien, Rhodanien and Urgonien which are probably the equivalents of part of our L. Greensand beds.

The Jurassic group is divided after the manner usual in English classifications, into Lower, Middle and Upper. The Lower including the Bath freestone and accompanying beds from the so-called Inferior Oolite to the Cornbrash; the German method is to include the Lias in the Lower Jurassic, against which are many reasons. As Bradford-on-Avon is so near to us we are interested to notice that it forms one of the divisions of the fourth column; the Bradford Clay with us is a band less than 10 feet thick and therefore hardly worth making into a separate division; it may be considered as a clay band of the Forest Marble, a local feature; it is at the base where it does occur, and forms a convenient point of separation between the Bath Oolite proper and the Forest Marble, but its characteristic fossil Apiocrinus Parkinsoni is found equally in the Forest Marble, and the clay itself dwindles down to almost nothing in places. The Bradfordian of the Table however

represents our Bath Oolite proper, Bradford Clay, Forest Marble and Cornbrash, altogether no great thickness with us; but of somewhat greater importance on the Continent. From an English point of view then it would seem more suitable to have used the word "Bathonian" here, taking it from the third column where it stands for our "Lower Oolite;" it must be confessed, however, that confusion may arise between the "Lower Oolite" and "Inferior Oolite" of English classifications. The arrangement of the Table is very clear and there is no inconsistency in using "Bathonian" as denoting all our Lower Oolites, for they all occur round the town of Bath; at the same time it is giving the word a wider acceptation than was given to it by D'Orbigny, but is at any rate preferable to the German use of the English word "Dogger" for the Lower Oolites.

Our "Inferior Oolite" so called is divided into two divisions supposed to correspond to the Murchisonæ and Humphresianus zones. With us the Parkinsoni zone is included in the Dundry or Inferior Oolite, being inseparably united with them and below the Fuller's Earth Rock, but according to the Table it ranges higher in some places (see column headed "French Alps.")

The top division of the Lias corresponds to our Midford or Upper Lias Sands, the former designation being much preferable to the latter, for it is still a question whether it is best classed with the U. Lias or Inf. Oolite. The palæontological affinities may be with the Lias, but the petrological characteristics are unquestionably rather those belonging to the Inf. Oolite. It would seem to be much the same in Suabia judging from the position given to the beds by Professor Quenstedt.

The Middle Lias is called "Cymbien" from *Gryphea cymbium* a leading fossil.

Professor Renevier some twelve years ago proposed the term "Hettangien" to represent the Planorbis beds; this is a most convenient expression and far preferable to the Infra-Lias of some authors; the beds well deserve the rank of a sub-division of the

Lias, for the fauna as a whole is very different from that of the Gryphæa beds.

The Rhætic is placed as the lowest division of the Lias; it will ever be an interesting page in geological history as it gives some hint of transition of the Trias into Lias. The Amphibian and Fish fauna of the older group is elbowed in our Aust Bonebed by the Ichthyosauri and Plesiosauri of the newer—reptiles at that time of the "coming race." The word Rhætien occurs in two columns of different values (so does Portlandien,) the Professor says that he was unable to avoid this; it may detract a little from the logical strictness of the Table but can have no practical inconvenience.

We may pass now to the Permian Epoch—under it the first thing that catches our eye is the "Dolomitic Conglomerate" of Bristol (there is a mark of interrogation however to it,) we are not surprised at this—it was so accounted once by the discoverers of the two reptiles found herein near Bristol. It is now however frequently called Bunter. There is no doubt however that it is not of Bunter age. Mr. W. Sanders, F.R.S. ¶ has shown that the Conglomerate is of no one precise age but occurs at any level in the N.R.S. (Keuper,) thinning out in one place and coming in again at a higher level. Latterly Sir C. Lyell has also placed it in the Keuper, * it is probably even partly as late as Rhætic age. It seems to lie above the Rhætic or be intercalated with it in places in S. Wales. Last year Mr. H. W. Woodward † intimated much the same thing from his survey of the Mendip district. Professor Morris and Rupert Jones ‡ class it as Keuper.

There is very little of the Palæozoic beds to be seen in Switzerland, the coal beds with fossil ferns occur near Bex, &c. Beyond this the table has to give us chiefly the groupings as developed in other countries. The Mountain Limestone figures under the name of "Condrusien:" it is well developed in Belgium, where Prof. De

¶ Brit. Assoc. Rept. for 1849, p. 65.

* Students Elements of Geology, 2d. each, p. 111 and 361.

† Somerset Arch. and Nat. Hist. Soc. Proceedings for 1873.

‡ Synopsis of Lectures on Geology p. 71 (1870.)

Koninck divides it into an upper and a lower division. The Lower Limestone Shales and Calciferous Sandstones, &c., of Ireland are grouped under the name of "Ursien" from the locality of Bear Island, whence the fossil flora has been minutely described by Prof. Heer.

The classification of the Devonian agrees with that used in England. When we come to the Lower Palæozoic, of course the classification has to be taken entirely from England or N. America or Bohemia: Prof. Renevier has adopted mostly English names for the divisions of the fourth column.

We have before alluded to the use of the word Silurian and Silurique in different columns, the one made equivalent to our Lower Palæozoic, and the other about equal to the Lower Silurian of English authors, being opposed to the "Murchisonien" which stands for our Upper Silurian. If one part of the Silurian system is to be called after Murchison, perhaps the other might have been named after Sedgwick; that would have been one way of avoiding the double use of the same root. Lyell's arrangement of the Lower Palæozoic will be preferred by Englishmen probably. The table is based on the latest researches of Dr. Hicks as far as the subdivisions of the Cambrian is concerned.

We can see that there must have been an immense amount of work in drawing up this table of Sedimentary Rocks, from the quantity and compactness of the information which it conveys. A scheme too of this sort is very easy to refer to,—the eye catches the object sought at once, and the parallelism of the groups is better fixed in the memory after seeing them in tabular form than perhaps in any other way. We can therefore heartily recommend it to English students, more especially as there is no table published in England which includes nearly so many foreign groupings of beds.

List of Resident Birds, Summer and Winter Visitors, and occasional Stragglers, observed in the Bristol District.

BY E. WHEELER.

THE physical aspects of the Bristol district, consisting of open Downs, well wooded heights and valleys, rivers, streams, and muddy estuaries of the Avon and Severn, afford very favourable haunts for a considerable number of our indigenous birds, and summer and winter visitors. Although not so favoured as the east and south coast for Continental stragglers, yet at intervals we are visited by some few and attractive species.

The majority of our birds are of course arboreal. The sea coast with its granite, chalk, or limestone cliffs, the haunts and breeding places of the Colymbidæ, Alcadæ, and Laridæ, is beyond our limits, consequently members of these families form but a small part of our lists. The Steep Holm, in the Bristol Channel, is perhaps the nearest point where the common Sea Gull breeds. In the autumn and winter the banks of the Avon and Severn abound with them, as well as Black-headed, Herring, occasionally Great and Lesser Black backed Gulls, and Common Tern.

The absence, too, of extensive and unfrequented Marsh lands, the natural habitat of the Scolopacidæ and Anatidæ permits us to number but a few of these interesting families, most of the species of which are uncommon.

Thirty years since our British birds numbered about 320 species. About 73 have since been discovered, making up to the present time 393 species. Of these the Bristol district includes about 108 residents, 37 summer, and 27 winter visitors, including a few rare stragglers, numbering altogether 167 species.

The *Falconidæ* form but a very small group. The "Honey Buzzard" has been twice killed at Leigh; specimens also of the "Common Buzzard" have been shot, and the "Kite" once. The "Hobby" and "Merlin" are the only others of sufficient rarity to need notice; it is many years, however, since either have been observed.

The *Strigidæ* are represented by the two ordinary species, the Brown and Barn Owl. The short and long-eared species are both rare.

None of the *Laniadæ* have been noticed, excepting our ordinary summer visitor, the Red-backed Shrike.

Amongst the small group of the *Muscicapidæ* only the Pied Fly-catcher need be mentioned as being of great rarity, having occurred once only.

The ordinary species of the *Merulidæ* are well-known resident or winter visitors. The Ring Ousel is a scarce summer visitant.

Amongst the *Sylviadæ* no species have been observed requiring any special remark. The Reed, Sedge, and Grasshopper Warblers are all uncommon. Nightingales have been these last two or three years much more numerous. The Bearded and Crested Titmice are both absent from the *Paridæ*. All the others are tolerably common, *P. Major* and *Cœruleus* especially so. The one representative of the *Ampelidæ*, the Waxwing, has occurred at rare intervals.

The common species of the *Motacillidæ*, *Anthidæ*, and *Alaudidæ* are all pretty generally distributed, the "Rock pipit" being the only really local bird. The rare visitor, *A. alpestris*, the Shore

Lark, was captured by a birdcatcher in the neighbourhood in 1873, and exposed for sale with Yellowhammers; it was, I believe, purchased for a shilling, and given to the Zoological Gardens, in whose aviary it is still retained.

In the *Emberizidæ* we have one rare winter visitor, the Snow Bunting, which has been shot at Avonmouth; the Cirl Bunting, occurs occasionally. The *Fringillidæ* are very well represented. The Brambling is local; also the Tree Sparrow. Haw Finches have these last two or three winters been more abundant, remaining till late in the spring. Many breed here; at Henbury, and near Almondsbury, nests and eggs have been taken. The Mountain Linnet is a rarity; as also the Crossbill; both have occurred at Leigh and Henbury. We have another rarity in the family *Sturnidæ*, the "Rose-coloured Pastor:" this has been once shot in the vicinity. The *Corvidæ* all belong to us with the exception of the Chough. The Hooded Crow and the Raven are both rare. The families forming the group of *Scansores* call for no special remarks, except the occurrence of the Hoopoe some years since, both Great and Lesser Spotted Woodpeckers are uncommon. Another rare straggler, the Bee Eater, visited Stapleton a few years ago. Several specimens were seen by Mr. G. Harding frequenting the beehives in his grounds, three of which were shot by him.

The Kingfisher may be found in several parts of the neighbourhood. The *Hirundinidæ* and *Caprimulgidæ* are each represented by the generally distributed species known almost everywhere: so also with the *Columbidæ* and *Phasianidæ*. Two species of the *Tetraonidæ*, the Black and Red Grouse, have been shot, but of great rarity. The Quail is another rare visitant. The *Charadriidæ* and *Ardeidæ* families are not numerous, the commoner species only have hitherto been noticed, with the exception of the Bittern, which has been shot near Portishead and Clevedon. Amongst the *Scolopacidæ* too we number but a few, the Green Sandpiper perhaps being the rarest. The Whimbrel, Bartailed Godwit, and Redshank are occasional visitors. The Spotted Crake and Grey Phalarope are rare members of the next two families,

occasionally occurring. The remaining group of the *Natatores*, comprising the Ducks, Divers, and Gulls, &c., leave little to remark, a few are common; the chief rarities hitherto noted have been the Canada Goose, Shoveller, Scaup Duck, and Goosander, amongst the *Anatidæ*, and the Great Northern Diver, two of which were shot in the Floating Harbour, amongst the *Colymbidæ*. The common species of the *Alcadæ*, the Guillemot and Razor Bill, are with us only occasional visitants. The Cormorant and Shag are also occasionally met with off Weston-super-mare. The only rarities amongst the *Laridæ* is the Little Gull, shot in 1850 at Portishead. The Stormy Petrel has occurred there also, but these waifs and strays from the open sea are but accidental visitors, there being so little congenial to their habits in the muddy waters of the Severn.

In compiling the following List, I have to acknowledge the kind assistance given by the Rev. Marcus Richards, Mr. Geo. Harding, and Mr. C. Charbonnier, without whose help most of the rarer species would have been absent.

Order 1. RAPTORES.
Family. FALCONIDÆ.
Genus. *Falco.*

Falco abicilla - White Tailed Eagle - Indigenous - very rare
(One shot in Doddington Park, Gloucestershire. Date not known. Rev. M. R.)

F. peregrinus - Peregrine Falcon - Indigenous - very rare
(Shot some years ago. Date not known. G. H.)

F. subbuteo - Hobby - Summer visitor - occasional
(First occurred some years ago. A very fine example caught by a birdcatcher a few weeks since; in Mr. G. Harding's possession. Preserved by Mr. Charbonnier. These birds are captured in this way as often as shot. G. H.)

F. æsalon - Merlin - Summer visitor - occasional

(Two or three have been shot at intervals. No record.)

F. tinnunculus - Kestrel - Summer visitor - generally distributed

(Frequent occurrence. Breeds at Leigh, and a year or two since in St. Vincent's Rocks.)

F. nisus - Sparrow Hawk - Summer visitor - generally distributed

(Frequent occurrence. Breeds at Leigh and Henbury. Becoming scarce, from continual destruction.)

Falco milvus - Kite - Indigenous - rare

(One shot some years since. No record.)

F. buteo - Buzzard - Indigenous - rare

(Two shot at Leigh. One in my possession.)

F. apivorous - Honey Buzzard - Indigenous - rare

(Two at Leigh. No record of date. G. H.)

F. cyaneus - Hen Harrier - Indigenous - rare

(Has occurred some years since. No record. G. H.)

Family. STRIGIDÆ.

Genus. *Strix.*

Strix otus - Long-eared Owl - Indigenous - rare

(Portishead. Local list.)

S. brachyotus - Short-eared Owl - Indigenous - occasional

(Leigh. Portishead.)

S. flammea - White Owl - Indigenous - generally distributed

(Leigh. Kingsweston. Not common.)

S. aluco - Brown Owl - Indigenous - generally distributed

(Leigh; Stoke Bishop; Stapleton; Kingsweston,)

Order 2. INSESSORES.

Group 1. DENTIROSTRES.

Family. LANIADÆ.

Genus. *Lanius.*

Lanius collurio - Red-beaked Shrike - Summer visitor - gen. dis.

(Frequent at Leigh, Hallen, Stapleton. Insects some times found impaled by this bird.)

Family. MUSCICAPIDÆ.
Genus. *Muscicapa.*

Muscicapa grisola - Spotted Fly Catcher - Summer visitor - gen. dis.
(Frequent at Leigh Woods; Orchards, Gardens, and Plantations.)

M. atricapillæ - Pied Fly Catcher - Summer visitor - rare
(One only at Ashton, many years since.)

Family. MERULIDÆ.
Genus. *Turdus.*

Turdus viscivorus - Missel Thrush - Indigenous - tolerably common
Frequent on Downs and Leigh.

T. pilaris - Fieldfare - Winter visitor - abundant
(Commoner some winters than others.)

T. musicus - Song Thrush - Indigenous - abundant
(Well-known everywhere.)

T. iliacus - Redwing - Winter visitor - abundant
(More numerous than Fieldfares, and usually arrives earlier.

T. merula - Blackbird - Indigenous - abundant everywhere
(Pied varieties occasionally occur.)

T. torquatus - Ring Ousel - Summer visitor - rare
(Occurs occasionally at Leigh Woods and Stapleton. G. H.

Family. SYLVIADÆ.
Genus. *Accentor.*

Accentor modularis - Hedge Sparrow - Indigenous - com. everywhere

Genus. *Sylvia.*

Sylvia rubecula - Robin - Indigenous - common everywhere

S. phœnicurus - Redstart - Summer visitor - abundant

S. rubicola - Stonechat - Indigenous - local
(Not very common. Downs; Ashton; Leigh.)

S. rubetra - Whinchat - Summer visitor - local
(Not common. Ashton; Leigh.)

S. œnanthe - Wheatear - Summer visitor - generally distributed
(Downs; Leigh; Avonmouth.)

S. locustella - Grasshopper Warbler - Summer visitor - not com.
(Seldom seen, from its shy habits. Sometimes heard. Leigh; Portishead; Knowle.)

S. phragmites - Sedge Warbler - Summer visitor - very local
(Near Nailsea; Stapleton.)

S. arundinacea - Reed Warbler - Summer visitor - very local
(Stapleton, occasionally,)

S. luscinia - Nightingale - Summer visitor - generally distributed
(In Woods. Commoner than formerly. Clifton Down; Leigh.)

S, atricapilla - Blackcap - Summer visitor - generally distributed
(May be heard almost everywhere.)

S. hortensis - Garden Warbler - Snmmer visitor - generally dis.
(Plantations, Gardens, &c. Less frequent than preceding.)

S. cinerea - White Throat - Summer visitor - generally dis.

S. curruca - Lesser do. - Summer visitor - not common

S. sibilatrix - Wood Wren - Summer visitor - tolerably common
(In Woods.)

S. trochilus - Willow Wren - Summer visitor - local, not common
(Stapleton; Ashton.)

S. rufa - Chiff-Chaff - Summer visitor - abundant

Genus. *Regulus.*

Regulus Cristatus - Gold Crested Wren - Indigenous - gen. dis.
(Woods, Plantations.)

Family. PARIDÆ.
Genus. *Parus.*

Parus major - Great Titmouse - Indigenous - abundant everywhere
(Woods, Gardens, &c.)

P. cœrulus - Blue Titmouse - Indigenous - abundant everywhere
(Woods, Gardens, &c.)

P. ater - Cole Titmouse - Indigenous - local
(Leigh Woods; Stapleton.)

P. palustris - Marsh Titmouse - Indigenous - generally distributed

P. caudatus - Long-tailed Titmouse - Indigenous - tolerably common

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Family. AMPELIDÆ.
Genus. *Bombycilla.*

Bomb. garrula - Bohemian Waxwing - Winter visitor - very rare
(Has occurred at intervals. Ashton.)

Family. MOTACILLIDÆ.
Genus. *Motacilla.*

Motacilla alba - White Wagtail - Indigenous - rare
(Durdham Down; Leigh Woods. Rev. M. R.)

M. Yarrelli - Pied Wagtail - Indigenous - abundant everywhere

M. boarula - Grey Wagtail - Indigenous - not common
(Chiefly seen in winter.)

M. flaveola - Ray's Wagtail - Summer visitor - local
(But not uncommon where it occurs. Clifton Down; Avonmouth; Ashton; Stapleton.)

Family. ANTHIDÆ.
Genus. *Anthus.*

Anthus arboreus - Tree-pipit - Snmmer visitor - tolerably common

A. pratensis - Meadow-pipit - Indigenous - very common
(Leigh; Clifton; Avonmouth; Sea Mills.)

A. aquaticus - Rock-pipit - Indigenous - local, but tolerably common
(Banks of Avon.)

Group 2. CONIROSTRES.
Family. ALAUDIDÆ.
Genus. *Alauda.*

Alauda arvensis - Skylark - Indigenous - abundant

A. arborea - Woodlark - Indigenous - local
(Leigh; Shirehampton.)

A. alpestris - Shore Lark - Occasional visitor - very rare
(One caught near Bedminster, by a birdcatcher.)

Family. EMBERIZIDÆ.
Genus. *Emberiza.*

Emberiza nivalis - Snow Bunting - Winter visitor - very rare
(Two or three times at Avonmouth.)

E. miliaria - Common Bunting - Indigenous - generally distributed
(Not common.)

E. schœniclus - Black-headed Bunting - Indigenous - local
(Not common. Stapleton; Avonmouth.)

E. citrinella - Yellowhammer - Indigenous - abundant

E. cirlus - Cirl Bunting - Indigenous - rare
(Has occurred at Wrington.)

Family. FRINGILLIDÆ.
Genus. *Fringilla.*

Fringilla cœlebs - Chaffinch - Indigenous - abundant everywhere

F. montifringilla - Brambling - Winter visitor - local
(Occurs some years in tolerable abundance. Stapleton.)

F. montana - Tree Sparrow - Indigenous - rare

F. domestica - House Sparrow - Indigenous - common everywhere

F. chloris Greenfinch - Indigenous - abundant

F. coccothraustes - Hawfinch - Winter visitor - local
(Occurs every winter on Clifton and Durdham Downs, and Henbury. Some remain to breed.)

F. carduelis - Goldfinch - Indigenous - local
(Much less frequently seen than formerly.)

F. spinus - Siskin - Winter visitor - local
(Occurs most winters at Stapleton and Leigh.

F. cannabina - Linnet - Indigenous - common

F. linaria - Lesser Redpole - Indigenous - tolerably common
(Leigh Woods and Stapleton.)

F. montium - Twite - Indigenous - rare
(Occasionally at Leigh.)

Genus. *Pyrrhula.*

Pyrrhula vulgaris - Bulfinch - Indigenous - tolerably common
(Clifton Down and Leigh.)

Genus. *Loxia.*

Loxia curvirostra - Crossbill - Winter visitor - rare
(Occasionally. Henbury.)

Family. STURNIDÆ.
Genus. *Sturnus.*

Sturnus vulgaris - Starling - Indigenous - common everywhere

Genus. *Pastor.*

Pastor roseus - Rose-coloured Pastor - Summer visitor - very rare
(One shot at St. Philip's Marsh. G. H.)

Family. CORVIDÆ.
Genus. *Corvus.*

Corvus corax - Raven - Indigenous - rare
(Occasionally at Leigh and Stapleton.)

C. corone - Crow - Indigenous - local
(Common on banks of Avon.

C. cornix - Hooded Crow - Indigenous - rare
(Has occurred once or twice, but no exact locality known.)

C. frugilegus - Rook - Indigenous - common everywhere

C. monedula - Jackdaw - Indigenous - common
(St. Vincent's Rocks and Leigh.)

C. pica - Magpie - Indigenous - generally distributed

C. glandarius - Jay - Indigenous - common in woods

Group 2. Scansores.

Family. Picidæ.

Genus. *Picus.*

Picus viridis - Green Woodpecker - Indigenous - generally dis.
(Leigh; Clifton Downs; Stapleton; Ashton,)

Picus major - Great spotted Woodpecker - Indigenous
(Occasionally met with. Leigh; Ashton.)

P. minor - Lesser spotted Woodpecker - Indigenous
(Occasionally met with. Leigh; Ashton.)

Genus. *Yunx.*

Yunx torquilla - Wryneck - Summer visitor - generally distributed

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Family. Certhiadæ,

Genus. *Certhia.*

Certhia familiaris - Creeper - Indigenous - tolerably common
(Everywhere.)

Genus. *Troglodytes.*

Troglodytes vulgaris - Wren - Indigenous - common
(Everywhere.)

Genus. *Upupa.*

Upupa epops - Hoopoe - Straggler - very rare
(Two individuals shot some years since.)

Genus. *Sitta.*

Sitta Europæa - Nuthatch - Indigenous - tolerably common
(In woods.)

Family. Cuculidæ.
Genus. *Cuculus.*

Cuculus canorus - Cuckoo - Summer visitor - common
(In woods and parks.)

Group 4. Fissirostres.
Family. Meropidæ.
Genus. *Merops.*

Merops apiaster - Bee-eater - Summer visitor - very rare
(Several shot a few years since by Mr. G. Harding, Stapleton. Frequenting beehives in garden.)

Family. Halcyonidæ.
Genus. *Alcedo.*

Alcedo ispida - Kingfisher - Indigenous - local, not common
(Stapleton; Ashton; Avonmouth; Sea Mills.)

Family. Hirundinidæ.
Genus. *Hirundo.*

Hirundo rustica - Swallow - Summer visitor - common
(Everywhere.)

H. urbica - Martin - Summer visitor - common
(Everywhere.)

H. riparia - Sand Martin - Summer visitor - local
(Stapleton.)

Genus. *Cypselus.*

Cypselus murarius - Swift - Summer visitor - generally distributed

Family. CAPRIMULGIDÆ.
Genus. *Caprimulgus.*

Caprimulgus Europœus - Nightjar - Summer visitor
(Generally distributed in woods.)

Order 3. RASORES.
Family. COLUMBIDÆ.
Genus. *Columba.*

Columba palumbus - Ring Dove - Indigenous - generally distributed
(Woods and copses.)

C. œnas - Stock Dove - Indigenous - generally distributed
(Woods.)

C. turtur - Turtle Dove - Summer visitor - not common
(Leigh.)

Family. PHASIANIDÆ.
Genus. *Phasianus.*

Phasianus colchicus - Pheasant - Indigenous - abundant
(Woods and preserves.)

Genus. *Tetrao.*

Tetrao tetrix - Black Grouse - Indigenous - occurs occasionally
(Portishead; Mendip Hills.)

T. scoticus - Red Grouse - Indigenous - occurs occasionally
(Mendip Hills.)

Genus. *Perdix.*

Perdix cinerea - Partridge - Indigenous - generally distributed

P. coturnix - Quail - Summer visitor - rare
(Stapleton. G. H.)

Order 4. GRALLATORES.
Family. CHARADRIIDÆ.
Genus. *Charadrius*.

Charadrius pluvialis - Golden Plover - Indigenous - occasionally
(Banks of river.)

C. hiaticula - Ringed Plover - Indigenous - common
(Banks of Avon and Severn.)

C. morinellus - Dotterell - Indigenous - rare
(Flat Holmes. G. H.)

Genus. *Vanellus*.

V. cristatus - Lapwing - Indigenous - common
(Leigh; Portishead; Failand.)

V. melanogaster - Grey Plover - Indigenous - occasionally
(Avonmouth.)

Genus. *Strepsilas*.

S. interpres - Turnstone - Indigenous - rare
(Avonmouth; Portishead.)

Genus. *Calidris*.

C. arenaria - Sanderling - Indigenous - rare
(Near Clevedon.)

Genus. *Hæmatopus*.

H. ostralegus - Oyster Catcher - Indigenous - occasionally
(Banks of Severn.)

Family. ARDEIDŒ.
Genus. *Ardea*.

A. cinerea - Heron - Indigenous - not uncommon
(Banks of Severn; occasionally on Avon; and Leigh;)
Abbot's Pond.)

A. stellaris - Bittern - Summer visitor, sometimes resident - rare
(Near Clevedon and Portishead.)

Family. SCOLOPACIDŒ.
Genus. *Numenius.*

N. arquata - Curlew - Indigenous - common
(Avonmouth; Portishead.)

N. phœopus - Whimbrel - Indigenous - local
(Occasionally seen, Portishead; Avonmouth. Rev. M. R.)

Genus. *Totanus.*

T. calidris - Redshank - Indigenous - occasionally occurs in winter
(Avonmouth.)

T. ochropus - Green Sandpiper - Summer visitor - rare
(Near Yatton. G. H.)

T. hypoleucos - Common Sandpiper - Summer visitor - occasional
(Portishead; Banks of Avon.)

Genus. *Limosa.*

L. rufa - Bar-tailed Godwit - Winter visitor - occasional
(Portishead.)

Genus. *Scolopax.*

L. rusticola - Woodcock - Indigenous - not uncommon
(Leigh; Henbury; Durdham Down, occasionally.)

S. gallinago - Common Snipe - Indigenous - not uncommon
(In marshy places; Portishead; Durdham Down; Stapleton.)

S. gallinula - Jack Snipe - Winter visitor - occasional
(In marshy places; Ashton; Clevedon.)

Genus. *Tringa.*

T. variabilis - Dunlin - Indigenous - common
(Banks of Avon and Severn.)

Family. RALLIDÆ.
Genus. *Gallinula.*

G. crex - Landrail - Summer visitor - common
(In fields generally.)

G. porzana - Spotted Crake - Summer visitor - rare
(Ashton.—C. C. Stapleton.—G. H,

G. chloropus - Moorhen - Indigenous - common
(Ashton; Stapleton: Leigh; Avonmouth; Henbury.

Genus. *Rallus.*

R. aquaticus - Water Rail - Indigenous - occasional
(Ashton; Stapleton.)

Family. LOBIPEDIDÆ.
Genus. *Fulica.*

F. atra - Coot - Indigenous - rare
(Near Clevedon. G. H.)

F. platyrhyncus - Grey Phalarope - Winter visitor - rare
(Clevedon. Rev. M. R.

Order 5. NATATORES.
Family. ANATIDÆ.
Genus. *Anser.*

Anser ferus - Grey-legged Goose - Winter visitor - rare
(Avonmouth,)

A. segetum - Bean Goose - Winter visitor - occasional
. (Avonmouth.)

A. berniola - Brent Goose - Winter visitor - rare
(Avonmouth.)

A. Canadensis - Canada Goose - Winter visitor - rare
(One shot some years since.)

Genus. *Cygnus.*

C. musicus - Hooper Swan - Winter visitor - rare
(Avonmouth.)

Genus. *Anas.*

A. tadorna - Common Shieldrake - Indigenous - not uncommon
(Banks of Severn; Barrow. G. H.)

A. clypeata - Shoveler - Winter visitor - rare
(Portishead.)

Anas acuta - Pin-tailed Duck - Winter visitor - rare
(Avonmouth. Rev. M. R.)

A. boschas - Wild Duck - Indigenous - not common
(Ponds and Marshes.)

A. crecca - Teal - Indigenous - rare
(Clevedon; Portishead.)

A. penelope - Widgeon - Winter visitor - rare
(Portishead; Ashton.)

A. perspicillata - Surf Scoter - Winter visitor - rare
(Ashton. Rev. M. R.)

A. ferina - Pochard - Winter visitor - occasional
(Nailsea.)

A. marila - Scaup Duck - Winter visitor - rare
(Portishead. G. H.)

A. clangula - Golden Eye - Winter visitor - rare
(Near Banwell. Rev. M. R.)

Genus. *Mergus.*

M. merganser - Goosander - Winter visitor - rare
(Wraxall. G. H.)

Family. Colymbidæ.

Genus. *Podiceps.*

P. minor Little Grebe - Indigenous - occasional
(On the Avon.)

Genus. Colymbus.

C. glacialis - Great Northern Diver - Winter visitor - very rare
(Two specimens in Floating Harbour some years since.)

Family. ALCADÆ

Genus. *Uria.*

U. troile - Guillemot - Indigenous - occasional
(Weston-super-Mare. C. C.)

Genus. *Alca.*

A. torda - Razor Bill - Indigenous - occasional
(Weston-super-Mare. C. C.)

Family. PELECANIDÆ.

Genus. *Carbo.*

C. cormoranus - Cormorant - Indigenous - occasional
(Weston-super-Mare. C. C.)

C. cristatus - Shag - Indigenous - occasional
(Weston-super-Mare. C. C.)

Family. LARIDÆ.

Genus. *Sterna.*

S. hirundo - Common Tern - Indigenous - occasional
(Severn. Has been shot at Rownham Ferry.

S. arctica - Arctic Tern - Indigenous - rare
(Portishead.)

S. nigra - Black Tern - Summer visitor - rare
(Avonmouth. Rev. M. R.

Genus. *Larus.*

Larus minutus - Little Gull - occasional visitor - very rare
(One shot at Portishead, 1850.)

L. rudibundus - Black-headed Gull - Indigenous - not common
(Severn. Rownham Ferry.)

L. trydactylus - Kittiwake - Indigenous : occasional
(Avon and Severn.)

L. canus - Common Gull -] digenous - Common
(Avon and Severn.)

L. fuscus - Lesser Black-backed Gull - Indigenous - occasional
(Avon and Severn.

L. argentatus - Herring Gull - Indigenous - frequent
(Avon and Severn.)

L. marinus - Great Black-backed Gull - Indigenous - occasional
(Portishead; Avonmouth.)

Genus. *Lestris.*

L. Richardsonii - Richardson's Skua - Winter visitor - very rare
(Once shot at Clevedon. Rev. M. R.)

Genus. *Thalassidroma.*

T. pelagica - Storm Petrel - Indigenous - rare
(Portishead.)

On the Age of the Cannington Park Limestone, and its relation to the Coal Measures South of the Mendips.

BY E. B. TAWNEY, F.G.S., F.Z.S.

Read at the General Meeting, November 4th, 1875.

WE propose, in a few words, to consider the age of the Cannington Limestone, as it seems to us to have much connection with the question of the probability of finding coal south of the Mendips—at any rate, south of the western part of the chain.

The question of finding Coal under the Thames' Valley was ably put forth by Mr. Godwin Austen, F.R.S., in 1856 (Q.J.G.S. xii, pp. 38-73) and the relations of the Mendip axis, with its supposed accompanying Coal Measures, to the secondary rocks was touched upon. It was more fully entered upon in the Report of the Coal Commission, being noticed by Prof. Prestwich (loc.cit. 47 and 163—165) in his contribution to the volume, and his views are summarised in the main Report (p. xii).

Messrs. Bristow and Woodward * of H.M. Geological Survey, in a communication to the "Geological Magazine" (vol. viii, 1871) have also discussed the question and mentioned the Cannington Limestone therewith. They consider this limestone of Carboniferous age, their words being "at Cannington Park we have the Mountain Limestone presenting its ordinary features, as they are so well displayed in the corresponding beds at Clifton, on the Mendip Hills, and in S. Wales," (loc. cit. p. 504). They argue from this fact both the probable existence therefore of a trough of coal measures between here and the Mendips, and that there "is no reason to suppose a great change in the Carboniferous strata immediately south of the Mendips." The reason of this last remark,—to use their own words—being the following: "the opinion has been expressed by Prof. Prestwich and Mr. Etheridge that, possibly to the south of the Mendips the Coal Measures might assume the Devonian type of Coal Measures."—The fear expressed by the latter authors being that they might be therefore worthless, as it is well known that the Devonshire Culm contains no series of workable Coals. As far as Mr. Etheridge is concerned, this opinion is in accordance with his views elsewhere expressed, that the Limestone of Cannington Park is of Devonian age.

We hence have two opposite views to deal with, one that the Limestone is Devonian and that it might be probably succeeded by Culm beds rather than productive Coal Measures; the other, that of Messrs. Bristow and Woodward, that the Cannington Park Limestone is Carboniferous, and that there is, therefore, no reason to suppose the Coal Measures, if present, to be of another type than north of the Mendips.

Certainly we agree with the latter, but the only reason they give for the determination of the Carboniferous age, is that of general lithological resemblance, which is, perhaps, hardly sufficient in the face of much divided opinion.

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* See also Quarterly Journal of Science, 1873, vol. III, N.S., p. 108.

It will be well therefore to review shortly the facts which have been accumulated by various workers, bearing on this question, and so incidentally sketch roughly the history of opinion relating thereto.

Leonard Horner in his "Sketch of the Geology of the S. Western part of Somersetshire" published in 1816 (Trans. Geol. Soc., 1st. series, vol. III, p. 365), considered the Limestone of transition (Devonian) age—his words are as follows.

"In the eastern part of the district, near the banks of the Parret, below Bridgwater, there is a nearly insulated hill called Cannington Park, totally different in structure from any other part of the country described in this paper. On the north side it rises directly from the marsh land, with a gradual slope to the height of 232 feet above the plain: on the south side it is not altogether cut off from the lateral branches of the Quantock hills. It is composed of a highly crystalline Limestone of a pearly grey colour, having a very close grain, and when struck, giving a ringing sound like that of glass. I examined it with very great care in order to discover whether it contained any organic remains, and particularly at the decomposed surfaces, and in those places where the stone was bruised by the blow of hammer, which generally detects any madrepores that exist in a limestone, but I could not find the slightest trace; and some of the quarriers who had worked there for several years, told me that they had never found anything of the kind. It contains, here and there, contemporaneous veins of a very pure white and opaque calcareous spar, and the strata are traversed by large veins of calcareous spar. In the latter veins the spar is distinctly crystallised, and in layers parallel to the sides of the vein, a circumstance which points out a marked difference between them and the veins of contemporaneous formation. On the north side of the hill there is a vein of red sulphate of Barytes about 3 feet thick in the widest part. This substance is not contiguous to the limestone, but is accompanied on each side by a reddish brown ochreous earth. Nor does the vein itself appear to intersect the limestone but to be interposed between two vertical masses. The

barytes contains copper pyrites and green oxide of copper, and in the limestone near the vein I found quartz crystals scattered through the mass, giving it an appearance like a porphyry. I also observed in some places carbonate of copper in the limestone. In going over the top of the hill, which is very much covered by vegetation, the ends of the strata appear above the grass in many places in a vertical position and running between N.E. and S.W.; but on coming to the quarries where the rock is extensively exposed, I found that through it is evidently stratified, it is so shattered and crossed by rents in every direction, that it was impossible for me to discover what were the true planes of stratification, the internal structure of the stone affording no indication. Judging, however, from the more general direction of the masses, I think they may be said to be either for the most part vertical or at least very highly inclined and running between N. and S. I did not discover the least appearance of slate, or any circumstance that could connect this limestone with the subordinate beds in the graywacke series of the neighbouring hills, except its proximity to them. It more nearly resembles the Plymouth limestone than any other I am acquainted with; and although that has been found to contain both madrepores and shells, there are great portions of it where no traces of organised bodies can be discovered. It is also very probable, that by a more minute examination, they may be found in the limestone of Cannington Park, for it has, certainly, very much the appearance of what is called a transition limestone. and there are laminœ of calcareous spar dispersed through it which are strong indications of organic remains. It produces a very pure white lime, which is carried to a great distance."

The Rev. D. Williams mentions it in a paper read before the British Association in 1837. In the section given in the Report of that meeting (vol. vi, p. 95), the Cannington limestone is placed below the Foreland sandstone, at the base of the Devonian rocks: this paper was written "to determine the relative age and order of the Culm-field and its floriferous shales and sandstones."

In a paper on "as much of the Transition or Grauwacke system as

is exposed in the counties of Somerset, Devon & Cornwall, (Proc. Geol. Soc. III., p. 115 & 158;) again similar views are expressed. Subsequently this author seems to have considered it of the same age as the limestones of the Quantocks, *i.e.*, M. Devonian,—see his manuscript observations quoted by Mr. Baker, (Som. Arch. N. H. Soc. Proc. for 1852, p. 129.)

The late Professor Phillips discussing the palæontological relations of the Devon & Somersetshire rocks, in the work published by the Geological Survey in 1841, (Palœozoic Fossils p. 142-3,) places this limestone in the Ilfracombe group; the fossils determined by him were *Cyathophyllum Damnoniense* and *Ceriopora similis*, the former a Devonian coral, the latter both Devonian and Carboniferous. I am not aware that this Devonian coral has been found subsequently, and it would be desirable to have some confirmation of its occurrence. Sir H. De la Beche considered the limestone to belong to the Devonian system of the Quantocks and in the older editions of the Geological Survey map, it was accordingly coloured as Devonian and taken as of the same age as the adjacent Limestones of the Quantocks.

In 1851 the late Mr. Baker, of Bridgwater, writing on the Geology of Somerset, (Som. Arch. Soc. I, p. 129,) notices the occurrence of encrinites and corals in it, while in a second article in 1853,* he boldly abandons views taken by the Geological Survey and previous authorities, and advocates its Carboniferous age. He here announces the discovery fossils which would point to this conclusion: these were *Conocardium*, *Productus*, *Orthis*, *Terebratula* and Corals; he considers these to agree with fossils in the Mountain Limestone of the Mendips. It is a pity however that their specific names are not given. He notices the "Oolitic structure and general resemblance of the stones," (*l. c.*, p. 129,) to the Mendip Limestone. The fragments of Encrinites are so abundant that they have been noticed by all observers.

* "The Cannington Park Limestone," Som. Arch. N. H. Soc. Proc. III., p. 125-131, for 1852.

Mr. T. H. Payne also places it in the Mountain Limestone series (Som. Arch. Soc. Proc. for 1854, p. 105;) writing on the "Geology of the Quantocks," he remarks that it is very different to any limestone observed in these hills.

Mr. Etheridge's views are expressed in a contribution "on the physical structure of West Somerset and N. Devon and on the palæontological value of the Devonian fossils." Q. J. G. S., (1867,) xxiii., p. 568—698. As Palæontologist to the Geological Survey, he was asked by the Director to undertake a review of the Devonian Rocks, in connection with the claims of some geologists that these should be merged into the Carboniferous system. We may therefore conclude it contains his ultimate opinion and this is that the limestone is a Devonian outlier.

A section is given which represents the Cannington limestone included in the mass of Devonian rocks of the Quantocks, part of which crop out close by in the village of Cannington. There are no reasons given why the limestone is considered Devonian, and no fossil evidence is adduced. The adjoining limestones of the Quantocks yielded to the survey Palæontologist characteristic Devonian corals, but their absence here is passed over.

Sir H. De la Beche had most cautiously remarked of this limestone (Report on Devon and Cornwall, p. 55,) "that the connection with the rocks of the Quantocks cannot be traced satisfactorily. At Cannington itself, on the S. of the limestone, the lamination of the slate has a southern dip, and if this should coincide with that of the true beds, the slate would appear to rest upon the limestone, *unless* some great fault should occur." In the face of considerable difference of opinion Mr. Etheridge seems to have been rather unfortunate in the way he has touched upon this question.

The most valuable contribution on the age of the Cannington Park Limestone, is that by Mr. S. G. Perceval, of Henbury, (Geol. Mag. ix., p. 94, 1872.) He has here determined the Corals, which had been presented by Mr. Baker to the Taunton Museum: they are as follows:—*Lithostrotion Martini, irregulare, aranea Clisiophyllum turbinatum, Syringopora ramulosa.* He adds "The

Limestone in parts is oolitic in structure, and is identical in character with that developed in the neighbourhood of Bristol. It undoubtedly belongs to the Upper Carboniferous Limestone." With this conclusion we certainly agree and as the determinations may be relied on, it almost renders any further discussion unnecessary.

From our own cursory observation of the limestone we have obtained *in situ* an undoubted specimen of Lithostrotion irregulare, which is quite conclusive as to the age; several specimens of solitary corals were seen in the rock, poorly preserved, and which we could not identify specially. Of shells we found several crushed specimens, perhaps *Terebratula hastata* or possibly an *Athyris*, also a small *Producta elegans* or young *P. punctata*.

We are indebted to our companion, the Rev. H. Winwood, for an example of what looks like *Atrypa reticularis*, but we are unable to say whether it be really such; also for a portion of stem of *Actinocrinus*.

We follow Messrs. Bristow, Woodward and Perceval in recognising a lithological resemblance to the Carboniferous Limestone of the Mendips both in colour, structure, mode of weathering, jointing, &c., it mainly resembles the Carboniferous Limestone.

The joints are numerous and persistent; the main joints have a N. & S. direction. In the large quarry, at the S. E. end of the hill, and indeed generally the dip is rather obscure. At one end of the quarry, where we found the corals, the dip is plainly to the S. W., at an angle of about 30°, but at the other side of the same quarry the beds seem to arch over and the quarrymen pointed out to us that near the floor in this part they dip steeply in the opposite direction. The mass is therefore part of a dome or fold.

The limestone is intersected by many strings and veins of Triassic age; some filled by a red breccia bounded by a lining of white calc-spar; the Trias breccia of the veins contains pieces of limestone, the whole most firmly cemented together. These veins contain red sulphate of Barium, (the Barytes was noticed by

Leonard Horner,) and specks of green Carbonate of Copper, in fact the Barytes may be seen abundantly placed as an ornamental spar on the tops of walls round houses.

We may take it then as proved that the limestone is Carboniferous. It follows at once that it is totally disconnected with the Quantock series, seen a few hundred yards off, and its isolated position becomes one of great interest

The Fault spoken of by Sir H. De la Beche must certainly exist; what the nature of the dislocations are we may remain ignorant of for some time, but it seems certain that the Carboniferous Limestone must exist as a roll, or anticlinal, (of which Cannington Park is a small portion,) which probably holds for some way eastward under the Somersetshire marshes; certain it is that this is the most southern exposure of the Mendip Limestone, and hence N. of it under the Somersetshire Flats, we most probably have the productive beds of the Coal Measures, or part of them. It seems likely too, that they are at no great depth, as the New Red, or Lias occupy the surface. A boring of 600 feet in the centre of the marshes might probably determine the question.

Hence therefore as Messrs. Bristow and Woodward have already said, our hopes of finding coal here are materially strenghtened when once we have put aside the notion of the Cannington Limestone being of Devonian age, and have recognised the Carboniferous character as proved by fossils.

Insect Anatomy.

BY DR. H. FRIPP.

Read at the General Meeting, March 2nd, 1876.

ALTHOUGH it cannot be supposed that every member of our Naturalists' Society should take as great an interest in descriptions of insect structure as might be felt by a student of anatomy or entomology, I would fain hope that the subject may still prove sufficiently attractive to be received with some degree of favour even by a general audience. Were any special plea needed in defence of insect anatomy, I might fairly urge that insects are of infinite service and profit to man, or that they force themselves on his attention by becoming at times a plague to him or that they exemplify the most curious life-habits, and present, in many instances, the most beautiful objects in nature; and I might add that an interest is quickly acquired in any subject by becoming better acquainted with it. Against all such arguments, however, the objection prevails that "we cannot all do everything;" and this applies more forcibly in our own busy age than in any preceding one. And where all are so busy that very few care to turn aside from their own pursuits, or from other pressing interests

of the moment, it is vain to remark upon the tendency engendered by division of labour to similar division, (*i.e.*, narrowing of interest) in the respective objects of our study.

But in addressing a society of naturalists—whose meetings are professedly held for interchange of thought and work and whose vitality is best shown in the variety of research undertaken by its members—it seems to me more fitting to rely upon the interest we all take in each others work than to insist upon the special importance of the subjects which we investigate. There is a community of interest in the commonwealth of science, as well as in the republic of letters, in which all students are privileged to share and to which all may appeal. One may plant the seed, another may water it, and again others may carefully tend its growth, until in due time and season fruit is matured which will be gathered by all who hold knowledge in honour, with a sense of enjoyment enhanced by variety of choice as well as flavour. And those will enjoy in highest degree who are themselves labourers in the garden of nature, and who, in contemplating the work accomplished by their associates, find relief from the strain of their own labours, and a genial spur to their scientific zeal when perhaps most needed.

What I have to bring before the Society consists of anatomical details of a somewhat technical nature, which I cannot pretend to introduce with any flourish of trumpets, and which I shall not attempt to embellish with glowing descriptions of the marvels of insect life, or by anecdotes of curious habits, which may be found in abundance in all our books. It is rather my aim to direct attention to the less cultivated but more practical field of research which here lies open to the naturalist, a field peculiarly his own, full of promise and, though demanding some exercise of skill and patience, worthy of his best energies. And it is my hope that some of our members may be induced to take up a study which will interest them more and more as they advance, and which will yield valuable materials for our evening discussions.

I have fixed on a particular example of insect anatomy for several reasons. In the first place, I believe that precise knowledge of

insect structure, derived from a given source, is of greater value than vague statements gathered from the general surface of insect history; and secondly, because I have not met with any detailed account of the anatomy of the cricket in our science journals, although the creature is familiar to us as household words. Another reason for my selection was, that the insect is always to be got, so that any spare time could be given to its examination, without fear of being forced to leave the work incomplete for want of material. For the same reason, also, anyone can obtain and examine it for himself, and so be in a position to criticise and correct my results.

In this communication I limit myself to the descriptive anatomy of a single insect because the lessons to be learnt from each example—whatever be the one selected—are best learnt by an exhaustive study of it, no part or detail being omitted on the supposition of its being already known. Facts freshly observed, and communicated direct by the observer, impress more, and come with more interest than statements compiled from works already known. Even if not new, they have, for the time and purpose, the freshness of re-discovery. and a lasting value if they settle what was not definitively accepted. Nor is the time spent in such examinations disproportionate to the results gained. For the anatomy of a single insect not only illustrates that of all its kind but also affords a vantage-ground from which we get an insight into the general nature of insect organisms, and recognise variations and contrasts as well as likeness of structure, so that time is saved in all subsequent investigations. Each onward step gives us possession of new standards of comparison whereby to interpret structural peculiarities, and additions or omissions of parts and organs and lastly, any one item in the long series of facts may throw unexpected light upon phases of development, and so help to widen the basis upon which higher generalisations may be founded.

What has hitherto been accomplished in insect anatomy has been of great service in furthering the purposes of the entomologist, as well as of the comparative physiologist. It is so obvious as scarcely to need remark, that classifications once based on external appearances

and unscientific fancies have undergone frequent remoulding upon the more precise indications of anatomical structure, and have improved in proportion as our knowledge of the relation between insect-life habits and their external and internal organisation becomes more accurate. It was not, for instance, until Cuvier demonstrated the broad distinctions in the organs of vegetable life, that the incongruous animals once associated under the heading "Insecta" were arranged in their respective divisions of Crustacea, Arachnida, Myriapoda, and Insecta, now defined by striking contrasts of circulating and respiratory apparatus by different number and arrangement of body segments, limbs, &c. &c., and by distinctive characters of sensory and nerve organs.

But in the classification of insects, properly so-called, physiological anatomy has been less happily applied. The division of insects into groups, according to external signs of metamorphosis does not correspond with any principle of natural affinities between the members of the order so constituted.

Metamorphosis as a basis of classification necessarily fails when the visible changes differ so greatly in degree amongst animals nearest in affinity. And, moreover, its real significance as an indication of the process of evolution through which all creatures pass was so imperfectly recognised by those who first employed insect metamorphosis as a means of classification, that two of the three divisions were founded on a more or less absolute *negation* of metamorphic phenomena. So far as the unequal prominence of visible metamorphic changes may assist the entomologist in distinguishing his orders, it might be accepted for what it is worth: But the true anatomical expression of metamorphosis points rather to resemblances than differences to homologies than analogies to homogeneity of structure rather than heterogeneity. For as in its physiological aspect, metamorphosis reveals an underlying unity of action throughout the whole animal kingdom, so from its anatomical analysis we discover unity of structural elements, and their modes of evolution—the differentiations which ultimately ensue being the result of special individual conditions. In short, metamorphosis

belongs to a more recondite chapter of biology as a portion of the higher generalisations of developmental law; and though it affords truly wonderful and instructive glimpses into insect evolution, is misapplied in the limited uses of classification.

But other classifications founded with more success on permanent external features demonstrate the value of insect anatomy. In particular, the anatomy of the mouth and accessory appliances has proved of great importance. For its masticatory or suctorial character has a definite relation to the insect's nutritive organs, its food and life habits. Then, as secondary characters the presence or absence of wings with their number and arrangement, together with difference of antennæ, limbs and feet, offer many distinctions which have a direct connection with the modes of life of each species so characterised. In all classifications the various life habits afford natural and simple means of characterising insects, obviously, because it is more easy to observe these than to determine the anatomical peculiarities with which they are associated.

It is, therefore, not surprising that the nervous system plays so little part in any scheme of insect classification. The homogangliate character assigned to insects, in common with other divisions of articulata, admits indeed of considerable variation; but the infinite diversity of external characters of the insect's body is not accompanied by such obvious differentiations of nerve organs as would serve for purposes of classification. It cannot be doubted, however, that all the powers and faculties of insects expressed in their life habits, stand in close connection with the degree in which cephalic thoracic or abdominal ganglia are developed. From the relation, size, and complicity of the nerves and Ganglia of these three divisions and of the sensory organs, the probable conditions of the insect's existence may be fairly premised and the particular phase of metamorphosis of some, probably of all, (if we were sufficiently acquainted with their nerve anatomy), may be at once declared from the corresponding condition of dorsal chord, as I shall have occasion to shew in the sequel of this paper.

Thus it appears that insect classification has improved, so far as

proper use of structural indications has been made. But classification is itself only a *means*, not an *end*, and insect anatomy has an important bearing on many other questions than those which occupy the Entomologist. I propose, therefore, to devote a few minutes to the consideration of those physiological aspects of insect life, which offer most promise of interest, and justify that closer scrutiny of structural details to which I have invited attention.

It is seldom that popular enquiry and anatomical investigation run together. But, if at any time, or upon any question, it is when the mysteries of organic life and animal automatism become subjects of speculation.

On the popular side, insect life has always suggested a belief in some form of "*soul-life*" as our German friends would term it. On the scientific side, insect-nerve physiology has yielded important éxperience, and thrown great light on the specific functions of nerve and ganglionic centre.

In the several orders of Articulata, we see the machinery of automatic action in its simplest and most complex forms, free from many complications which render the phenomena in animals of higher cerebral organisation more obscure. In the insect, the study of reflex action rises in significance proportionately with the perfections of special sensory functions, and of those actions, called "instinctive," which govern the whole organism. And the constructive type of the instruments by which all these functions are performed is especially suggestive, while the field of psychologic debate is greatly narrowed by observing the peculiar association and co-ordination of the several insect organs and faculties. In former times the minds of philosophers were much exercised in discussing the limits of volition and the antagonism betweem instinctive and rational acts. But as soon as reflex action was discovered, or rather explained, and its observed occurrence in the higher animals and man himself made us familiar with unconscious automatism, the inferior creature was at once dispossessed of its supposed right to a "soul-life." At the present moment, the continually extended observation of automatism, which seems to keep pace in its sphere

of action with every added cerebral function, has led to its being accepted by many as the *end* as well as the *beginning* of our sentient existence. And if consciousness, *i.e.* the perception of our own sensations, acts, and thoughts, be also the outcome of organic action, the mental calibre of man himself, no longer postulated by metaphysicians, becomes a question of how many missing links there may be between man and his *congeners*.

But while the philosophers have "moved on," the old belief, that insects possess the volitional powers now almost denied to man, remains with those who have not followed modern movement, and even our boasted civilisation is often unfavorably compared with the insect's social instincts. Its extraordinarily diversified life-habits—solitary or gregarious, predatory or timorous, parasitic or social; upholding regularly constituted polities, monarchical or republican; and, for all we know, as polemically inclined as man himself—*seem* to imply the causal relation of insect action to will, and more than simulate the subjection of motive to thought. One thing is however certain, namely, that the modern doctrine of acquired and newly-inherited faculties does not apply to the insect so as to make it grow wiser by experience, except in its own generation. Yet the world is ready to affirm that an insect reasons because its acts appear rational to man, whilst our advanced philosophers are occupied in reducing seemingly rational acts of man to involuntary acts of his body, of which he is unconscious.

Now, to this see-saw of opinion no end can be foreseen until the disputants are all equally informed, and provided with the same armoury of weapons; nor until the whole evidence of organic mechanism is collected and sifted to its last detail. No one meanwhile will play a more useful part in the collection of this evidence than he who succeeds in working out some unsettled problem of homology of structure, or in clearing up some intricacy of nerve physiology. Nor will the naturalist anywhere find examples of organic structure more suited to render the solution of physiological or mechanical problems clear to our perception than in the class Insecta.

But if such applications of anatomical science be thought too profound for leisure hours—if we care not to dive into the secret recesses, and fix our searching gaze upon the inner nature of living beings and their affections, there remains still an infinite fund of instruction in studying the lighter subjects of insect anatomy. The external changes which indicate the phenomena of metamorphosis can nowhere be seen so clearly, and in such relation of sequence, as in the insect. For, in the higher animals, these phenomena are concealed because the development to which they are related occurs in the earliest phases of life, whilst in the lower animals they are disconnected and lost to view by absolute separation of the individual into quotient parts, which have a separate life in time, place, and space. But in insect metamorphosis, the anatomical changes are more striking because we can observe their sequence, and follow the different phases of existence as the organism is adapted for life in earth, air, or water. Nature here exposes her operations to the eye of the naturalist, and leaves her experiments ready to his hands, on his excursions, or at home, in his garden, his home, and even his fireside.

But apart from the marvellous changes of structure relating to metamorphosis of insects, the actual condition of each individual, whether in young or old, or any intermediate phases of its organism, presents such a variety of problems of mechanical construction in the adaptation of its bodily organs to the habits and external surroundings of its life, as must interest any person even but slightly acquainted with insect anatomy. The dermo-skeleton of Articulata in general, with its various forms of leverage, jointing, and modes of obtaining strength at one point, flexibility at another, rigidity at a third, expansion of surface with least expenditure of material and greatest saving of weight or bulk, is sufficiently striking in all, but in none so remarkable as in the insect division, whose wings, feet, antennæ, probosces, palpi, eyes, &c., have always excited attention and admiration. The transformations of this dermo-skeleton—now soft and silky, now encasing head, body, and limbs, in a panoply of armour, with heavily-jointed limbs and weapons of

offence and defence; now thinning into diaphanous skin and gossamer wing, bespangled with scales of exquisite beauty, whose markings send microscopists into transports of enthusiasm (and perplexity!) or covered with irridescent hairs, spines, thorns, and prickles of woful itching power, or emitting, to the dismay of the collector, strange odours and irritant juices from glands beneath, or again, armed with borers, grinders, pincers, saws, rasps, stings and lancets worked with an intensity of power which, if exerted by an animal of larger size and proportional muscular energy, would appal a Titan—in short a dermo-skeleton which illustrates so complete a repertory of mechanical contrivance, and enables the insect to perform in miniature all that bird, beast, and reptile can do, is a sufficient task for the most laborious student.

But in addition to this external, we find an internal anatomy of equal complicity, indicating in its highly specialised organs the capacity of an insect to conform to every circumstance and influence of its external surroundings.

It is worthy of remark that the class Insecta is not a mere connecting link in the chain of animal creation, but a kingdom whose members inhabiting earth, air, and water, illustrate the doctrine of adaptation under the most extreme conditions more completely than any other class. And whilst repeating the characteristics of other classes, and presenting various analogies with animals both above and below them, possess, in addition, individual and special characters of their own, and so special a place amongst the great divisions of the Invertebrata as to stand indisputably at their head. But, just as our ideas of life in its most elementary form are best exemplified in the least organised matter, so the most striking additions to, and extensions of this elementary life might be expected to be seen in organisms, in which the primary phenomena of living matter undergo the greatest changes and transformations under the physiological rule of adaptation to external influences. This is notably the case in insects, and must be so when we consider the extreme as well as middle ranges of insect life. And the result is seen not only in the

variety of life-habit but also in speciality of organs, and even in special perfection of individual tissues. For instance, the muscular energy transcends anything known of other animals. Attached to the strong dermo-skeleton, it enables the insect to resist crushing weights or to lift and drag them, to burrow into wood, to crush stone and even metal, with contractile force that would not be credited but for repeated trustworthy observation. *Strength* is not however its only property, for *rapidity of contraction* is such that the flight of a dragon fly or even a common house fly cannot be equalled by bird or beast. And the compound effect of strength and rapidity of action is manifested in leaping powers which no other animal exhibits. Anatomy shews, in fact, that insect muscle is the most perfect of known muscle tissues. But, further, this expenditure of muscular power implies correlative power of nutrition and excretion. Anatomy shews that the peculiar respiratory system of the insect converts the whole creature into a lung, and at the same time into a drainage apparatus, the excreta being gaseous. With respect to nutrition, the replacement of used up force argues the necessity of rapid assimilation for the ordinary expenditure rather than of stored up material, but the fatty tissues of the insect are very remarkable as a store of oxidisable fuel in concentrated bulk. The possible capacity of nutrition is, however shewn during the periods preparatory to metamorphic changes, when the amount of food taken, and increase of weight, are unparalleled in the history of any other creature. In the *active* phases of insect life, circulation is also more complete and special than is commonly supposed; not only do all cavities and interstitial spaces between the organs serve as blood channels, but the nerve trunks and ganglia are enclosed in sheaths which I consider equivalent to blood vessels or lymphatics, through whose walls interchange of fluids takes place, besides which, many of the finely ramifying tracheæ are apparently enclosed in canals filled with the circulating fluid. Considering, indeed, the penetration of every tissue of the body by terminal membranous tracheæ and the rapidity of aeration and gaseous exchange, it seems difficult to

understand why an insect hovering on the wing all day or darting through the air like a dragon fly should not dry up altogether, unless some provision existed for surrounding important organs with fluid. That the common belief in the physiological inferiority and anatomical imperfection of insect circulation is erroneous, further appears from the consideration of other changes involved in the "fast life," of our insect. And particularly from the conversion of the nutritious fluid into the remarkable series of products, secreted by the glandular organs which receive their supplies from circulating channels and lymphatic vessels.

Silk, honey, wax, cochineal, cantharidine, formic, and other acids, irritant fluids which excite disease in plants and animals, are all suggestive of the subtle chemistry of insect secretion which thus spreads good and evil upon the world around. The varieties of gland and other peculiar arrangements of insect structure by which such results are brought about, form therefore interesting points of anatomical enquiry.

There is yet another chapter of insect history, namely, *parasitic* life, which closely concerns us who suffer grievously from it, and which is mainly elucidated by anatomical investigation. In all these particulars the practical and scientific interests of mankind run together, whether in finding remedies for the plagues which *ignorance* of insect habits brings upon man, or in discovering the causes of ravages which devastate his crops, or in improving the management and increasing the productiveness of insects which yield him valuable materials. In relation with these practical issues stands the history of development and reproduction, which, so far as anatomical investigation has been prosecuted in this direction, reveals unsuspected facts, and leaves unexpected mysteries. The altered conditions and habits of the insect and its changed functions find equivalent expression in external "ecdysis," and internal "metamorphosis." But such revelations leave all unexplained mysteries more mysterious than before—such for example as the selection of place in which to deposit ova, immigration, and social instincts generally. Nor is the study of insect *sensation*

without its general as well as scientific interest. Does the sense of pain or pleasure influence the movements of insects? Is there any consciousness of sensation or retention of past sensation in the form of memory? Do the special senses, the perfection and acuteness of which are undeniable, influence the insect's action through a common sensorium, or does each reign independently over those actions of the body to which they stand in special relation· These are questions, a competent discussion of which is only possible when the physiological anatomy of cerebral and sensory ganglia has been thoroughly determined. Finally there remains that faculty which presents itself to different minds in such different aspects that it would seem scarcely possible for all to agree in discriminating between instinct and reason.

If, in the foregoing remarks I may seem to have laid myself open to the charge of falling into the vague generalities which I professed at the outset to avoid, I must ask you to bear in mind that I am not setting up any defence of Entomology as a study, but that what I have to say of the anatomy of the cricket necessarily bears on the general characteristics of insect structure, and that any question of physiological interest, arising naturally out of anatomical premisses, falls within the scope of my paper. A preliminary glance over the whole subject is therefore useful in indicating the precise facts which deserve special notice, and also the precise relation in which each fact stands to the general physiology of insect life.

I conclude these introductory remarks with a few words on the dissection and preparation of the soft parts of insects.

Much of our knowledge of internal structure has been gained by observation, under the microscope, of insects possessing a transparent integument. The larval forms are most suited for such examinations, and are best examined whilst living, when circulation or muscular action is to be studied. If the parts to be studied do not require hardening, it is best to dissect them out immediately after death, glycerine being used to keep them transparent, for when preserved in glycerine the structures can be left to any convenient time for examination. When spirit is used, hardening occurs in a few days,

after which the tissues shrink and become granulated and knotted together so as to break under dissecting needles; besides which they gradually get stained and opaque, so that they are not any longer well seen under the microscope by transmitted light. Water should not be used when dissecting, but the object must be floated in glycerine, and all fatty tissues removed as soon as possible.

The magnifying power under which dissection is carried on necessarily varies with the minuteness of the object—the lowest power under which the parts can be distinguished should always be chosen, because they can be kept better in sight and a firmer control over the movement of the dissecting needles exercised. With high power, the object escapes readily out of the field, and the needles are not easily brought to bear upon it. The power should be either a single lens, or a combination of lenses which magnifies without inverting the image.

Most insect preparations can be examined and made under a low power (5 to 25), but it is well to examine them under higher power during their preparation (50 to 75). When histologic elements are studied, still higher powers are needed. If, for instance, insect muscle is the object to be examined, the striation may be readily seen with quite low powers, but the arrangement of sarcous elements can be demonstrated only when powers varying from 400 to 800 are used. And by far the most beautiful objects are obtained when polarised light is used and advantage taken of the different refracting power of the discs and intervening substance. The ordinary striation of muscle fibre may be seen most perfectly in the muscles of the Thorax which naturally split up into long fibres, offering excellent specimens for study, (*e.g.* in the common house fly). For minute analysis of the sarcous mass, the muscles of mites (Trombidium) have been recommended, as the striation of such muscles is remarkably coarse and distinct.

Muscle must be taken from an insect immediately it is killed. It may sometimes be advantageously treated with alcohol, or osmic acid (weak solution) and prepared in glycerine. When studying the phenomena of contraction, which will be seen in various phases

along the length of the fibre, the muscle should be examined either in living insects, or in recently removed parts immersed in blood serum or some albuminous fluid (white of egg *e.g.*), or in glycerine, but never in water. In insect muscle preserved in spirit, especially if the insect has been dropped, while living, into the spirit, the varying state of contraction of different elements of the same fibre may be seen just as fixed at the time of death.

It frequently happens that the anatomist has not the opportunity of dealing with insects in the living or fresh condition. In such cases the specimen must be preserved in weak alcohol.

In the dissection of insects, different methods of treatment and manipulation must be adopted, according as it is desired to learn the structure of any particular organ, or to prepare and mount specimens, and economise so as to get the greatest number of preparations from a single insect. In learning the anatomy of any insect, not previously studied, a few specimens must be sacrificed by cutting and picking to pieces. But material may be saved by following same methodical plan. *External* parts can of course be studied as they present themselves, but it is worth while to preserve the dermo-skeleton, either whole, or in parts (sections), and this is best accomplished by boiling in solution of potash, then washing in cold water and removing with scalpel or brush any remaining soft parts (ligaments, membranes, tracheæ, &c.). To mount them, a suitable fluid, spirit, turpentine, balsam, glycerine, &c., must be used, and a convenient size and shape of cell chosen. The parts composing the mouth require special attention and should be separately mounted. The whole head may be divided in various directions, yielding longitudinal, transverse, and horizontal sections, each displaying some particular aspect. For example, a longitudinal section shews external and internal lateral views of the cranium with eye, antennal first joint (the antenna being cut off) mandible, maxilla, and palpi. Cross sections yield anterior and posterior views of the internal processes, separating the cranial and facial halves. Horizontal sections shew external and internal aspects of the vertex of the cranium with orbital and antennal sockets, labrum, &c., or

of base of cranium with maxilla and palpi, gula, labrum, lingula, paraglossœ, &c. The study of such sections of the dermo-skeleton, from which the soft parts are removed by boiling in solution of potash, is a necessary preliminary to the study of the very intricate anatomy of the soft parts contained within them, *e.g.*, Tongue, pharynx, æsophagus with its salivary glands and muscles, supra and infra-æsophageal ganglia and nerves, together with a mass of intra-cranial muscles arising from the inner surface of the cranium and internal processes, and attached to æsophagus, palate, and mandibles.

The student will be greatly assisted, and valuable time saved, by purchasing all good insect preparations which he can obtain commercially. Such preparations will probably be far better made and mounted than those which he makes for himself. But no cabinet of preparations will teach that knowledge of insect anatomy, which is to be gained only from actual dissection. The relation of the soft parts to the dermo-skeleton, and their own relative position to each other, can only be learnt in their entirety by those who dissect them in the fresh state and examine them *in situ*. Besides which, preparations of the most important and interesting parts are not usually made for sale, as they are difficult to dissect, and demand much time in preparing. But whilst dissecting for himself, the student will find every tissue and fragment of tissue well worthy of study from histiologic points of view, as well as on account of their anatomical relations. For instance, it is always well to examine fragments of muscle fibre scattered in the field, for the chance of securing good examples of nerve insertion under the sheath of the muscle, and distribution of its terminal filaments in the muscle substance. Fragments of gland structure sometimes offer unexpected yet beautiful specimens for preparation. The same may happen with varieties of gland in mucous membrane of intestines and other organs (testis, urinary tubes, hepatic tubes, &c.). Beautiful varieties of fatty tissue and dermoid tissues or exquisitely striated muscle (as in the coats of the dorsal vessel) or curious forms of tracheal ramification and wonderful networks distributed over or

penetrating through other tissues may be secured as chance prizes, if looked for amongst the debris after the principle organs have been secured.

The dissection and removal of the soft organs and finer structure is however attended with considerable difficulty when enclosed in a casing of such tough and resistent chitin integument as forms the dermo-skeleton of Coleoptera, Orthoptera, Hymenoptera and other classes. Of course this difficulty is greatest at the natural cinctures which mark the chief divisions of the insect into head, thorax and abdomen, and wherever internal processes connect the anterior and posterior surfaces, as happens for instance in the case of the cricket, both in the head and the thorax. The abdominal organs are easily removed from almost every kind of insect, but their continuity with the parts contained in the thorax can be preserved only by skilful manipulation. As the alimentary canal, and nerve chord, extend from head to tail, the integument must be slit up from end to end on the ventral side, but not directly in the median line, because it is best to remove the ganglionic chord with the æsophagus and intestine. In the instance of the cricket however the intra-cranial portion of the æsophagus, with its closely adherant infra—and supra-œsophageal ganglia, cannot be detached without first cutting off the head and very careful tearing out, as these organs rest upon a saddle-shaped osseous plate in the very centre of the cranial cavity. The ganglionic chord within the thorax is also enclosed between forks of internal osseous plates, but by following it up from the abdomen where it lies free, it can with a little care be got out entire. It is best to keep the whole insect floating in glycerine, the body being secured in any convenient way in a fluid-holding cell of suitable form.

To exhibit continuous systems of organs, and show their relative position to the several divisions of the external integument, longitudinal and transverse sections are useful. But these cannot be well made without a preparatory hardening process. If complete sections of the whole body are desired, the hardening process should be supplemented by soaking the parts in some material which will

preserve them in unchanged position under the action of the knife. The following plan which has been found most successful in making sections of diseased structures, and is employed by Professor Ranvier appears to me the most suitable for the purpose.

Place the parts (or the whole insect taking care to make such punctures or slits in the integuments as will allow the fluids used to penetrate thoroughly,) in alcohol for 24 hours, a time sufficient to to fix, without contracting the tissues. Then, in solution of picric acid for a few days, by which the spirit is expelled and the parts are again slightly hardened. After a few days wash in pure water and plunge the preparation into a weak solution of gum arabic which completely penetrates the tissues in a few days. Then remove and place in alcohol, which takes up the water, and the gum solidifies and yields a mass which resists uniformly the cutting blade—microtome, or razor—according to convenience. When the section is made, the gum dissolves out after soaking a little while in water, and the preparation can be floated in the fluid selected for preserving it. Cells are of course needed for preparations of larger parts and organs.

In the cricket's head, to which our attention is now directed, the same sections which were shown in preparations and drawings. displaying the dermo-skeleton, are equally serviceable in indicating the position of the soft parts. It will be seen from the drawings that this cranial dermo-skeleton contains within it a large number of organs which are facial rather than cerebral. The longitudinal vertical section in median line, shows the oral cavity, roofed by a long line of palate with the large and fleshy tongue beneath. At the isthmus of the jaws, suspended by muscles from the vertex of the cranium, the oral cavity becomes continuous with the œsophagus, situate high up, and resting on the central saddle formed by the union of four internal osseous processes, two of which descend from the vertex (one on each side,) whilst the remaining two rise from the base of the skull. From this central position the œsophagus, with its bunch of salivary glands, passes down between the two lower processes, into the neck. Nearly the whole of the intra-cranial cavity is occupied by the muscles which

arise from its internal surface and pass forward to the mandibles. The only really cerebral organs are the ganglion masses of the supra-œsophageal ganglion, which correspond with the *corpora quadrigemina* of the vertebrate brain, and the ganglia of sympathetic and vagus nerves. The vertical cross section, which the drawings represent as made immediately through the vertex of the head, shows the internal processes already mentioned, and, as seen in this section, they show how the cranial cavity is partitioned off, leaving special chambers (orbital, antennal) on each side, whilst in the longitudinal section the separation of cranial cavity from the face is seen to be effected by the same processes.

The central slice, obtained by a vertical cross section of the head, commencing from the top in front of the antennæ and carried down to the throat, and another parallel section made behind the antennæ and slicing with it the anterior portion of the cornea on each side, is a most important section. This central slice (about $\frac{1}{12}$ to $\frac{1}{16}$ in. thick) contains the whole brain with sympathetic and vagus ganglia, together with æsophagus and its salivary glands. Next in importance are horizontal sections from the occiput to the top of the nose. Looking towards the base, we see, as in the drawings and preparations, the symmetrical disposition of muscles, running on each side from the inner surface of the cranial cavity to the mandibles and maxillæ, with the central position of the æsophagus and the infra-æsophageal ganglion in front of it, also the tongue and the muscles connecting it with the anterior edges of the ascending internal processes, and the maxillary muscles on each side, with the maxillæ and all the parts of the lower jaw. And looking upon the surface of the section of the upper half of the cranium we see, as in the drawing, the symmetrical disposition of the orbital and antennal chambers and the optic ganglia on each side, the vault of the fauces and palate, and the inner surface of the labrum, &c.

As the descriptive anatomy of the head of the cricket will occupy a whole evening, the present rough sketch is intended merely to describe in a general way, the drawings before us, and so to enable those who examine the preparations on the table to under-

stand to what parts they belong. By examining the principal sections with a low power, a general map of the most important organs, and their actual and relative position, appears spread out before the observer. By a series of slices a corresponding map of each organ or parts of organs is obtained, and by piecing together the parts contained in each slice in their original order, the continuity and contiguity of the several structures is made out. In this way the drawings have been made which are now exhibited, and the result exemplifies the use of this method of obtaining exact figures, illustrative, first, of regional and ultimately of systemic anatomy. The details with which the general outlines are filled up, have been drawn from other series of preparations and dissections of parts obtained by varying the sections. The number and complicity of organs, and the minute details of structure, may surprise many who have not before considered the subject of insect anatomy, and their beauty and delicacy will, I hope, prove sufficiently attractive to counteract the tedium of listening to the descriptions which I have yet to offer.

(To be continued.)

NOTE.—As it has not been found practicable to reduce the diagrams, or to make fresh drawing from which illustrations to accompany the text could be produced in time for publication in this volume, the plates and descriptive text will follow in our next number.

[redacted]

On the Limits of the Optical Capacity of the Microscope.

BY PROFESSOR HELMHOLTZ, with a Preface by DR. H. FRIPP.

THE last number of our Proceedings contained a translation of Professor Abbe's article on the "Theory of the Microscope," originally published in Schultze's Archives. In that article, Professor Abbe stated the general conclusions at which he had arrived after a prolonged investigation of the optical laws affecting the transmission of light through the lenses of the microscope. These laws relate to 1.—The divergence of the rays of light forming a geometrical image. 2.—The brightness of that image. 3.—The dispersion of colored rays, and its consequences, and 4.—The diffraction of light occasioned by minute particles in the *objects* placed under, (or before) the microscope. In explanation of these several phenomena, a theory of the microscope was stated in general terms, the mathematical demonstration of this theory, and its various applications, being reserved for a future communication.

Simultaneously with Professor Abbe's researches, a most interesting investigation of the same subject, was completed by Professor Helmholtz, and appeared in Poggendorff's Annals (1874.)

The theoretical grounds taken by these two authors are identical, and their results, so far as the researches were directed to the same points also agree. But in each essay the mode of treatment is thoroughly independent, and the experimental proof of the conclusions respectively obtained is conducted by each writer in a separate and original method. The mathematical demonstrations omitted in Professor Abbe's article are fortunately supplied by Professor Helmholtz, and the two essays are confirmatory and supplementary to each other in several other respects, whilst in both we recognise that clearness of thought and precise knowledge of the subject treated, which justifies entire confidence in the conclusions. It seems therefore to me that Professor Helmholtz's essay should naturally follow in this number of our Proceedings. For, taken together, these two essays form the most complete and authoritative exposition of the optical principles involved in the action of microscope objectives, and the most trustworthy interpretation of that action, and consequently of the capacity of performance of such objectives, that have as yet been made public.

In introducing the first of these essays to the notice of our Society, I expressed my strong conviction of its high value as a contribution of really scientific character to the theory of the microscope. The essay of Professor Helmholtz deals somewhat more fully with that aspect of optical science which is known as physiological optics, and of which no physicist of our times has a more profound knowledge. This point of view had not been neglected by Dr. Abbe, but in my translation two short sections of his essay. which referred to brightness of image, and to certain enquiries connected with illumination of the image, were, for reasons mentioned in the preface, omitted. It is therefore so much the more satisfactory that Professor Helmholtz's essay enters fully into the subject. The peculiar conditions under which objects are seen when magnified by the microscope, can only be understood by studying both aspects, physical and physiological, in connection with each other. The laws of formation of optical images (when amplified by interposition of lenses,) and the laws of dispersion of

the rays by which these images are formed, help us to an interpretation of the physical agencies at work, and shew us also why the extreme amplifications employed render vision through the microscope more imperfect than through any other optical instrument, such as telescope, or camera. But the analysis of these physical agencies and effects, involves the consideration of the eye itself, as an optical instrument through which the microscope image must pass to reach the perceiving organ. And apart from the imperfections arising from aberrations and dispersions of rays in the instrument, other imperfections of the retinal image will be found in considering the more or less favorable conditions under which the microscope image enters the eye. The area into which the microscope image is collected at the eye spot (over the ocular,) varies in size with the amplification, and is smaller in proportion as the amplification is greater. And this variation of size is accompanied by variation in brightness of image and distinctness of detail. If the area of illuminated image entering the pupil is smaller than that of the pupillary aperture, loss of brightness is felt. For the condition of most effective illumination (brightness of image) is that which obtains when the area of image at the eye spot, and the area of the pupil, are equal. On the other hand, a small and intensely bright spot of light in front of the pupil presents the exact condition under which entoptic shadows obscuring the image are thrown with it on the retina. But as brightness of image is as necessary to distinct vision as any mere amplification of detail can be, it follows that a suitable relation of "aperture" to "magnifying power" must be maintained in every good objective; for "aperture" in this particular case means the measure of light admitted with the image-forming rays; and as a larger measure of light is required in proportion to the increase of magnifying power, so it is only when these two factors are suitably proportioned that details in the objective will be rendered clearly visible in its microscope image. And again, as respects the bundle of rays collected into a smaller or larger area at their entrance to the pupil, the regulation of illumination from without is better maintained with a

large "aperture" of objective by means of diaphragm openings and stops than by using stronger light with diminished aperture. Thus the management of illumination, and manipulation of the microscope to obtain good definition, though for the most part left to empirical practice, would be more easily and thoroughly acquired if the physiological laws were carefully studied. But another and far more serious deterioration of definition arises from excessive diminution of area of the image entering the pupil. This contracted area —the necessary consequence of the optical combinations used to obtain high amplification—has the same effect as any minute aperture through which a luminous object is viewed, and occasions, as is well known in physics, those diffractive effects which obscure the outlines of an image by making them overlap each other. On this fact is founded the whole argument of Professors Helmholtz and Abbe respecting the limits of microscopic vision, as well as the corollary which directly follows from it respecting the ultimate limits of minuteness to be assigned for vision of any and every kind of material atoms with the optical apparatus and materials yet employed. The theory of the microscope as interpreted by Helmholtz and Abbe on identical physical and physiological basis, is therefore of great importance in its general bearing in physical science, and the precise and comprehensive treatment of it in the following pages worthy of careful study.

As respects the translation now offered, it is only necessary to add that it was undertaken at the same time as that of Prof. Abbe's essay, and with exactly the same motives. Our readers will it is hoped bear in mind that the translator's object was simply to make known to those who could not otherwise so readily inform themselves, the views of scientific men abroad, whose authority on these subjects is at all events high in their own country, and whose teaching he had himself accepted with pleasure. No mention of English cotemporary work was needed therefore in the brief introductory notice of Dr. Abbe's article. Since its publication, however, the translator has been questioned respecting English contributions to the theory of the microscope, and he therefore ventures to add a few words on this subject.

One may be well excused from referring to the meagre optical chapters in our handbooks on the microscope, which might perhaps suit the "Boys'-own-book," but which contain neither demonstration nor diagram of the course of rays through any sort of modern lens system, nor even a rough application of its very elementary statements respecting refraction and reflection to any special formulæ of constructions, according to which the lens combination of an objective would be worked, or by which its performance would be tested. Nor can the favorite descriptive chapter of the instruments of various makers help anyone to a theory of the microscope. The opinions expressed by experts and authorities on definition, penetration, resolution, aperture, &c., as being so many separate *powers* or qualities, besides savouring strongly of a mythological period in the history of the microscope, have only retarded the search in the right direction, viz., by physical analysis and physiological study of optical phenomena for true causes of the effects observed. And in fine it must be confessed that our handbooks fail greatly in respect to theories of the microscope, however valuable their information on practical and mechanical subjects, and more especially on all branches of science involving skilful *use* of the instrument.

In the absence of such handbooks as the German students possess, and of which the work of Nägeli and Schwendener might be cited with admiration as an example, the scattered articles and shorter notices in our serials rise into comparative importance. But it will scarcely be contended that such desultory and disconnected communications and such remarkable disputes respecting easily determined facts, should be accepted as an equivalent of the systematic theory and practical demonstration which distinguish foreign study of optics applied to the microscope, from our yet unlearnt, or at least unwritten, micrographic science.

Various communications bearing more or less on the optical capacity of lens-systems constructed on given formulæ or for employment as "dry" or "immersion" objectives, have appeared in the Monthly Microscopical Journal, the Quarterly Journal of

Microscopical Science, and the Transactions of the Royal Society during present and preceding years. Of these, one series of papers published by Dr. R. Pigott claims to be a mathematical exposition of optical laws governing the divergence and dispersion of rays of light transmitted through different kinds of glass. Another series of papers by Mr. Wenham takes the practical direction to which English microscopists mostly incline. The communications of Mr. Sorby have enriched microscopic science with the most ingenious and successful applications of spectrum analysis that any country can boast. To all these gentlemen the English student may feel equally indebted for their respective labours. And the mention of these in juxtaposition with the work of so great an authority as Prof. Helmholtz and so conscientious a workman as Prof. Abbe, is not only due as a recognition of the individual services, but also as a proof of the higher direction of study now being pursued in England by amateur microscopists. As a humble member of this numerous class, the present writer ventures to refer to the early date of Mr. Wenham's communications when he stood almost alone as the pioneer of a future micrographic science, and to bear thankful testimony to the practical experience and sterling value of all that he has written. And he also cordially recognises the high aim and zealous study of Dr. R. Pigott, the direction of whose labours must ultimately prove most serviceable to all who desire to understand the real power and possible perfection of their favourite instrument. Any unfair spirit of criticism of matters so little appreciated by some of his critics is to be earnestly deprecated. One can only regret, whilst profiting by the opportunity of hearing all sides of a question, to be reminded of the woeful sentiment "*tantæne celestibus iræ.*" The vexatious partisanship of "aperture" and the disputed estimates of the performance of lenses constructed by this or that maker, must appear as overstrained and even ridiculous to the optician who can best guage his own or any other maker's work, as to those who care only to understand the principles of construction and to form a rational judgment of their action.

It is to be hoped that a more general agreement on the essential parts of the theory of the microscope will soon prevail, and that the exaggerated significance of certain matters too long discussed in our journals, will fade to its proper vanishing point.

The theoretical limits of optical capacity of the microscope.

In "Poggendorff's Annalen," for 1874, Prof. Helmholtz published an article, of which the following is a translation.

Whether, and to what extent, the optical performance of the microscope is capable of further improvement, is a question of the greatest moment for many branches of natural history. Doubtless, some progress, and notably through the revival of Amici's suggestion of immersion lenses adopted and carried out with such success by Hartnack, has been made, but each onward step is slow and faltering. We have, it is clear, arrived now at a point at which any trifling gain is effected with a disproportionate effort of mental as well as mechanical labour. And yet, so far as I can see, no one has been able to give any reason why this should be, excepting the common belief that the difficulty lies in overcoming the spherical aberration of lenses so small and of such quick curvation as is needed for objectives of very high magnifying power. It is not long since Herr Listing, one of the most eminent authorities on this subject, discussed, (Poggendorff's Ann. v. 136,) the means by which it might be possible to obtain amplifications ranging from 25 to 50,000 diameters, whilst in actual practice the ordinary range of *serviceable* amplification is at the present moment limited, to, from 400 to 800 diameters. Moreover the collective experience obtained by repeated efforts of practical opticians has taught us that all high amplifications combined with good definition (i.e., sharp delineation,) are obtainable only by instruments in which the objective admits a cone of light of very large angular aperture from each point of the object.

We have gradually arrived at that stage of improvement in the construction of instruments in which rays of light whose direction is nearly perpendicular to the axis of the instrument are passed into

and through the objective, and transmitted towards the ocular. This, it is true, happens only when a lens is used dry (i.e., the front surface in contact with air,) in which case rays inclined to the axis at angles up to 87½° actually do enter a well constructed immersion lens. This angle, however, diminishes to about 48°,* when the lens is used wet, that is when water is dropped between lens and covering glass as in the ordinary practice. This last named angle is nevertheless of far higher amount than any angle of aperture in the lens system of a telescope, or photograph camera, because with such oblique incidence, the spherical aberration, even in the carefully calculated and accurately executed lenses of these instruments would be simply intolerable. Why then, notwithstanding this, is the large incident cone of light in the microscope more advantageous than a narrow one of more intense light which would deliver an equal absolute quantity? The answer hitherto given to this question appears to me unsatisfactory. For the so-called "penetration" (i.e., the power of delineating by light and shadow and so rendering visible to the eye particles whose refractive quality differs but slightly from that of the matter surrounding them,) depends solely upon the proportion of the aperture of *illuminating* cone, to that of the cone passing from points of the object into the lens. Sufficient delineating shadow can only be got by narrowing the aperture of the illuminating cone, and a comparatively large cone can only be applied beneath the object when the cones of light passing from it into the objective are also large.

Now there does, in point of fact, exist in the microscope, a special cause which under the conditions here given produces a far greater aberration of rays from the focal plane than is occasioned by spherical and chromatic aberration, and which makes itself most felt just when the cones of incident light are smallest. This cause is diffraction.

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* These figures it must be borne in mind, denote in each case the angle included between outermost incident ray and axis of instrument, that is *half* the so-called "*angle of aperture.*"

If, perhaps, occasional allusion has been made to diffraction as a cause of deterioration of the microscopic image, I have yet nowhere found any methodical investigation into the nature and amount of its influence, but such an investigation shews, as will here appear, that diffraction necessarily and inevitably increases with the increase of magnifying power, and at length presents an impassable limit to the further extension of microscopic vision which limit, moreover, has been already closely approached in our newest and best instruments.

That diffraction and consequent obscurity of microscopic image must necessarily increase with increasing amplifications of the image, and this quite independently of any particular construction of the instrument, rests as a fact upon a general law which applies to all optical apparatus, and which was first formularised by La Grange * for combinations of any kind of "infinitely thin" lenses. This law has apparently remained almost unknown, perhaps because La Grange enunciated it in equations whose co-efficients have not characters which readily present clear ideas to the mind. In my treatise on physiological optics, I have given expression to this law in a somewhat more general form, namely, for centred systems of refracting curved surfaces with any singly refracting medium between them, and have endeavoured to formularise it in readily intelligible physical characters. I shall therefore recapitulate as briefly as possible this theorem and its demonstration. It holds good for every centred system of spherical refracting or reflecting surfaces through which rays pass with angles of incidence so fine as to form punctiform images of punctiform objects; that is to say refracts homocentric rays, homocentrically.

By the term, centred system, I designate one in which the centres of the curves of each refracting or reflecting spherical surface lie in the same straight line, the "axis" of the system. In front of such a system, and situate in its axis, let us suppose a luminous point belonging to some object lying in a plane at right

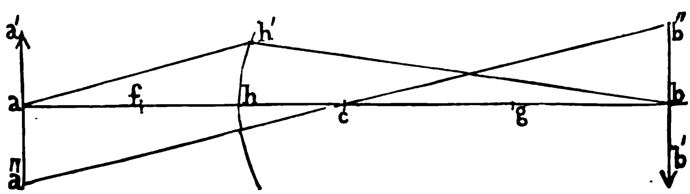
* Sur une Loi general d'Optique—Memoires de l'Academie de Berlin 1803.

angles to the axis, and from which rays pass through the system. The angle formed between any one of such rays and the axis, we shall call the divergence-angle of that particular ray. Any plane supposed to extend through the axis and along the ray, constitutes the incidence plane of that ray at the first refraction and will include, therefore, the same ray after its next refraction, and consequently after every subsequent refraction. Of this plane which will be divided in crossing the axis into two halves, one half will be treated as positive, the other as negative, and in correspondence therewith, the divergence-angle of the ray as positive or negative, according as the ray proceeds towards the positive or negative half of the plane. These postulates being settled the rule may be thus stated :—

Theorem.

In a centred system of spherical refracting or reflecting surfaces the product of the divergence-angle of any ray, the refraction index of the medium through which that ray passes, and the magnitude of the image to which the rays passing through that medium belong, remains unchanged by every refraction, provided always that the conditions of production of an accurate image are duly preserved. This product will therefore have the same value after emergence of the rays as it had before they entered the system of lenses.

Demonstration.



Let $a\ b$ be the axis of a lens system.

— $h\ h'$ —— one of the refracting surfaces.

— c the centre of its curve.

Let a be the point of convergence of rays, incident on $h\ h'$.
— b ——————— re-union of rays refracted by $h\ h'$.
— f the front principal focus.
— g the back ——————

Further let n' represent the ratio of refractions of the medium in front of hh'

n'' represent the ratio of refractions of the medium behind hh'

α' the positive divergence-angle $h'ah$ of the ray passing in first medium through h'

α'' the negative divergence-angle, in second medium —$h'bh$

β' the magnitude of image aa'' belonging to the rays of the first medium.

β'' the magnitude of image—$b'b''$ belonging to the rays of the second medium.

Firstly we have from similarity of triangles $aa''c$ and $bb''c$

$$\frac{\beta'}{\beta''} = -\frac{ac}{cb} \qquad (1)$$

Again, if we consider the short arc hh' of the refracting surface as a straight line at right angles to the axis ab

$$hh' = ah.\ \text{tang.}\ \alpha' = -\ bh.\ \text{tang.}\ \alpha''$$

Or substituting the angles for the tangents which is allowable here on account of the smallness of the angle:

$$\frac{\alpha'}{\alpha''} = \frac{bh}{ah} \qquad (2)$$

Multiplying equations (1) and (2), we get

$$\frac{\alpha'\ .\ \beta'}{\alpha''\ .\ \beta''} = \frac{ac\ .\ bh}{bc\ .\ ah} \qquad (3)$$

Now according to the known laws of refraction at a spherical surface, whose radius $hc = r$, the value of their principal focus is

$$F' = hf = \frac{n' r}{n'' - n'} \qquad F'' = hg = \frac{n'' r}{n'' - n'} \quad (4)$$

From which follow

$$\frac{F'}{F''} = \frac{n'}{n''} \quad (4^a)$$

$$F'' - F' = r \quad (4^b)$$

Further

$$\frac{F'}{ah} + \frac{F''}{bh} = 1 \quad \text{and} \quad \frac{F''}{ac} + \frac{F'}{bc} = 1$$

Or

$$\frac{bh}{ah} = \frac{bh - F''}{F'} \quad \text{and} \quad \frac{bc}{ac} = \frac{bc - F'}{F''}$$

Division of the last two equations gives

$$\frac{bh \,.\, ac}{ah \,.\, bc} = \frac{F'' \,(bh - F'')}{F' \,(bc - F')}$$

But by equation (4^b)

$$bh = bc + r = bc + F'' - F'$$

And

$$bh - F'' = bc - F'$$

Hence

$$\frac{bh \,.\, ac}{ah \,.\, bc} = \frac{F''}{F'} = \frac{n''}{n'} \quad \text{according to equation } (4^a)$$

Therefore equation (3)

$$\frac{\alpha' \,.\, \beta'}{\alpha'' \,.\, \beta''} = \frac{n''}{n'}$$

Or

$$n' \,.\, \alpha' \,.\, \beta' = n'' \,.\, \alpha'' \,.\, \beta'' \qquad (5)$$

q. e. d.

From this theorem it follows—

(Firstly), that when a ray (B) proceeding from a luminous point has an absolute smaller divergence-angle than the ray A, the divergence-angle of B will, after subsequent refraction, remain always less than that of A, because the product obtained by our theorem for B is from the beginning less than that obtained for A, and for the same reason must continue to be smaller after each refraction.

(Secondly), when two rays, starting from the same point on the axis, with equal angles of divergence, but following planes which extend in opposite directions through the axis, their divergence-angles continue to be equal after each refraction, a result which appears indeed at once evident from the symmetrical disposition of a lens system round its axis.

If now we imagine the illuminating rays, on their way to the object, to be circumscribed by interposing a diaphragm pierced with a circular opening whose centre coincides with the axial line, the plane of the diaphragm being at right angles with the optical axis, then those rays which pass through the opening close to its margin have all alike the largest divergence-angle, and retain the same relation after each fresh refraction. These rays obviously occupy the exterior outline of cones having a circular base, and whose axis is the optical axis of the lens system, and they constitute the boundary of the cone of light proceeding from the luminous point. The divergence-angle of these border rays is, in this case, throughout their entire course, the angle which the semi-aperture of the conical surface bounding the illuminating cone, measures.

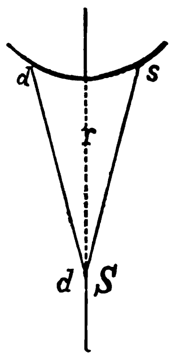
From this there follow, (firstly), certain important results in regard to the *photometric* conditions of the microscope image.

According to known laws of photometry, we may equate L the

quantity of light sent forth from the luminous point $d\,S$ upon another point $d\,s$, whose distance is r as follows where (r,N) and (r,n) represent the angles formed between the line r and the normals N and n.

$$L = J\frac{d\,S\,.\,d\,s}{r^2}.\ \cos\,(r,N)\ .\ \cos\,(r,n) \tag{6}$$

If now we understand by $d\,s$ the circular aperture of the cone of rays at one of the refracting surfaces, and by $d\,S$ a luminous point intersected by the axis so that r falls in the axial line.



Then cos. $(r,n)=1$, and $d\,S$. cos. (r,N) is the projection of $d\,S$ on a plane normal to the axis.

Let α be the angle of divergence of the rays directed to the periphery of $d\,s$, then $d\,s = \pi\,.\,r^2\,.\,\alpha^2$.

$$L = J\,.\,\pi\,.\,\alpha^2\,.\,d\,S\,.\,\cos.\,(r,N) \tag{6^a}$$

The same amount of light must also be contained in the same cone of rays continued through the following medium. And if we indicate the corresponding quantities by the signs J', α', dS', $N_{\prime}$ then

$$L = J'\,.\,\pi\alpha'^2\,.\,dS'\,.\,\cos.\,(r,N') \tag{6^b}$$

Now, dS' is the image of $d\,s$, and its projection—normal to the axis—dS' . cos (r,N') is the image of the corresponding projection of dS. We have therefore the proportion

$$dS\,.\,\cos\,(r,N) : dS'\,.\,\cos\,(r,N') = \beta^2 : \beta'^2$$

From which follows

$$J\,.\,\alpha^2\,.\,\beta^2 = J'\,.\,\alpha'^2.\,\beta'^2 \text{ and by equation (5)}$$

$$J : J' = n^2 : n'^2. \tag{6^c}$$

This gives the brightness with which the surface of image included within the outline of the illuminating cone shines, independent of the direction which dS and dS' have in relation to the axis, and of their distances from the surface of the curve (of lens.)

From this image (dS') we might pass on to consider a second, dS'', and so forth. It is obvious that between each following image and dS a similar equation would arise.

If we suppose the object and the image to lie in the same medium, then *the brightness of the optical image produced by rays which incline at very slight angles to the axis and perpendicular will always be equal to* (i.e., *neither more nor less than*) *the brightness of the object, except in so far as loss of light by reflection and absorption may occur.*

But this law should hold good without limitation of divergence-angle. For if it were possible to throw an image of any bright point sending forth its light according to the conditions above expressed, (namely, of rays circumscribed by a diaphragm aperture) which image should shine with greater intensity than the rule above given admits; then we could cause this bundle of rays to pass on as parallel rays through a plane end-surface into the air, and to fall into the eye of an observer; and in such case it would happen that an object would be seen more brightly illuminated through an optical instrument than it was before,—a thing contrary to all experience, whatever kind of transparent refracting material be used. Now, if this were possible with light it would also be true of heat, as might be shewn by application of similar reasoning; and then the law of equal radiation of bodies possessing equal temperature would be impugned.

But the equation which premised very slight divergence-angles of incident rays may be more precisely formulated, and so express the same result in the case of wide divergence-angles.

A more precise expression of the law of divergence-angles.

In equation (5) it is a matter of indifference whether we substitute for α its sine or tangent or similar functions which for indefinitely small α would be its equivalent. If we assume larger divergence-

angles of a pencil of rays whose section is a circle, then

$$L = JdS\int_0^a 2\,\pi.\ cos\ a.\ sin\ a.\ da = \pi\ JdS.\ sin\ ^2a.$$

If after a series of refractions the surface $d\ S_1$ is completely and accurately imaged in $d\ S_1$ with the brightness $\frac{n_1^2}{n^2}\ J_1$ and a_1 of the respectively appertaining divergence-angles; then the amount of light must be

$$L = \pi\ J\frac{n_1^2}{n^2}.\ d\ S_1\ .\ sin^2a_1.$$

as now, $dS\ :\ dS_1 = \beta^2 :\ \beta_1^2$ there follows from these equations,

$$n\ .\ \beta\ .\ sin a = n_1\ .\ \beta_1\ .\ sin\ a_1 \qquad (7)$$

which renders this formular of equation (5) valid for larger angles of divergence, assuming that β and β_1 are two images exactly reproducing each other, and whose surfaces are perpendicular to the axis.

Brightness of Image. When the pupil of the observer's eye is fully immersed in the pencil of rays proceeding from any point of an image, the observer will see the image illuminated as brightly as the object. This result was already announced by Lagrange. Unfortunately he had not investigated a second case, which happens to be more common just when high powers are used, namely, when the pencil of rays does not entirely occupy the pupil of the eye.

If a pencil of light having only small divergence-angle a_1 does not entirely fill the pupil when the image β_1 is situate at the proper distance of distinct vision, then the brightness H of the retinal image in that eye will be less than that entering the free eye H_o, whose pupil is entirely filled with light.

Let s indicate the distance of vision, p the radius of the pupil, then the area of its surface will be $\pi\ p^2$, the cross section of the pencil of light $\pi\ s^2.\ \sin^2 a_1$ and the general relation will bo

$$H : H_o = s^2.\ \sin^2 a_1 : p^2$$

Or using equation (7)

$$H = H_0 \cdot \frac{s^2}{p^2} \cdot \frac{n^2}{n_1^2} \cdot \frac{\beta^2}{\beta_1^2} \sin^2 \alpha.$$

The last medium in front of the eye must necessarily be air, therefore $n_1 = 1$, and if we indicate by α_0 the angle of divergence of the instrument measured in air according to Lister's method, then $\sin \alpha_0 = n \cdot \sin \alpha$. Putting the amplification $\frac{\beta_1}{\beta} = N$, then

$$H = H_0 \frac{s^2 . \sin^2 \alpha_0}{p^2 . N_2}$$

With an amplification N_0 by which the cone of light just fills the pupillary opening, and which we shall call the normal amplification of the instrument, $H = H_0$. Hence

$$N_0 = \frac{s}{p} \sin \alpha_0 \qquad (8)$$

And if α_0 remains constant,

$$H : H_0 = N_0^2 : N^2. \qquad (8^a)$$

If as was assumed

$$N > N_0$$

Whilst $H = H_0$ when $N \leqq N_0$.

That is to say.

The brightness of an image seen through the microscope is equal to that of light filling the unoccupied eye when the amplification is less than*

* Daylight is of course supposed, and a monocular microscope in use.

(or not greater) than the "normal" amplification, (*i.e.*, when the area of the ocular image just fills the pupil) *otherwise, with the same constant divergence of incident rays, the brightness is inversely proportional to the amplification of image.*

The normal amplification increases with the increase of the sine of the divergence-angle whose greatest value is 1 when this angle approaches a right angle, (as is the case with the widest-angled objectives).

Assuming 10 inches as the distance of clear vision for calculation of the amplified image, and $1\frac{1}{2}$ mm. as radius of pupil for bright illumination, the normal amplification is represented by the figures 166.7, and the brightness of image follows the following rates:

For an amplification of 333.3 .... $\frac{1}{4}$ brightness.
" " " 500.0 .... $\frac{1}{9}$ "
" " " 666.7 .... $\frac{1}{16}$ "

Which shows how rapidly the brightness must necessarily decrease with increasing amplifications.

Were it possible to conduct a hemispherical cone of light from an object lying in water into an immersion lens, and form therewith a correct image, all these amplifications might be raised in the proportion 1.335 to 1 whilst the brightness of image remained the same. But, as already remarked, every instrument hitherto constructed admits in air only, and not in water, a cone of incident light at all approaching to the hemispherical (180°).

The sectional area of the pencil of light entering the pupil may be determined empirically with ease. Focus the instrument on a bright field, and withdraw the eye from the ocular (keeping the direction of the axis of the microscope) and look at the ocular itself. Just in front of it will be seen a small bright circle against a dark ground. This is the optical image of the objective lens which the ocular (*i. e.* chiefly its field glass) forms. All light which comes through the objective and has passed the ocular must be collected in this image of the objective. It corresponds, therefore, to the area in which the several cones of light, transmitted from the bright points of the object, are collected at this spot. To gather

all this light and thus get the largest and clearest field of vision, the pupil of the eye must be brought to this spot. The relation between the area of the image and that of the pupil gives at once the ratio by which the brightness of the image is less than that of the object when looked at with the unarmed eye. The same brightness of image as of object exists only when the size of the image is equal to, or larger than that of the pupil.

In the instance of the telescope, Lagrange had already stated that the relation of size between the diameter of the objective and that of the picture of the objective formed by the ocular, is directly as the amplification, and he proposed to employ this ratio as a means of determining the amplification. With the telescope, however, such a decrease of brightness is not a necessary accompaniment of increased amplification, because the amount of incident light may be augmented indefinitely by enlarging the object glass or reflector. The aperture of the cone of light entering the microscope is, on the contrary, definitely restricted by the limits of the angle measuring that aperture.

So far, our demonstration shows that the relation between brightness of image and amplification is entirely independent of any particular construction of the instrument, provided only that it gives well defined images. An increase of amplification would only be possible, therefore, when a more intense illumination, *e.g.*, direct sunlight were employed, as indeed Listing had in view in the methods proposed by him for obtaining enormous amplifications. But here other difficulties present themselves, which arise from the very slight divergence-angle of the emerging rays, as appears in all cases of high amplification from the conditions of the equation representing the course of rays that enter an objective with wide divergence-angle.

The first difficulty is, that shadows of entoptic objects throng the field more densely as the area of this field at the eye spot (ocular image of the objective) becomes smaller. The retina is illuminated from this area as if it were the source of light from which proceeded all the rays that enter the eye. This area is at the same

time the basis of the collective pencils which belong to the several points of the object, and of its image on the retina, and its diameter, as before shown, varies in inverse proportion of the amplification. But the very conditions which must be fulfilled in order to obtain sharply defined shadows of objects within the eye are exactly what occur here, namely, that a strong light should enter the eye from a relatively small surface.

Whoever has, at any time, attempted to illumine the field of the microscope with direct sunlight, when employing a high amplification, will remember the peculiar spotty appearance of the field so obtained. Some of these spots remain fixed in the field, but others move with the motion of the eye. The first class of spots is due to dirt particles or imperfect polish of the ocular lenses; the second arises from shades caused by intervening opacities in the tissues of the eye—conjunctiva, cornea, crystalline lens, or vitreous humor.* This method has even been used to discover their existence, and is, in truth, a very suitable one. In proportion, however, as entoptic objects become more noticeable, will a greater number of finer details of microscope objects become obscured.

A second and inevitable disadvantage arising from the narrow divergence angle of the emerging rays shews itself in the occurrence of *diffraction phenomena*, whereby the outlines of visible objects are effaced, and at the same time doubled or further multipled. We have to deal here chiefly with diffraction phenomena as they appear when we look through a minute circular opening. A bright point of light (reflection of sun on the bulb of a thermometer), viewed through a pin point hole pierced in a card appears as a bright disc surrounded by alternate bright and dark circles. The apparent breadth of these rings, reckoned from minimum to minimum, corresponds very nearly to a visual angle, whose sine is equal to $\frac{\lambda}{a}$ where λ expresses the respective wave length of the light, and a the diameter of the opening. The outermost rings have exactly these dimensions, the

* But mainly from the retinal vessels, as shown by Heinrich Muller, vide Wurzburg Verhandlungen, Vol. 5, Page 411.—H. E. F.

inner are a little wider, and the radius of the innermost bright ring is $1{\cdot}220\frac{\lambda}{a}$. Now, as the smallest visual angle under which we can possibly distinguish two fine bright lines from each other may be fixed at 1 minute, the figures of the brightest yellow-green light, whose wave length = 0·00055 m.m., will be visible when $d = 1{\cdot}89$ m.m. Even with a somewhat larger opening the dispersion of a bright point into a circle or of a bright line into a streak must be noticeable.

When we look through such an aperture at any object which shows luminous points, the diffraction figures of the separate points partially cover each other, so that the fringe of dispersion circle of each single point, taken by itself, may not be recognisable. The effect, however, of this diffraction, since it changes every point into a small dispersion circle, obviously causes effacement of the true outline, just as happens when the accommodation of the eye is imperfect, in consequence of which very minute objects, which can be perceived only when the image on the retina is sharply defined, are unrecognisable. We may convince ourselves that this is the fact by a simple experiment. The retina is most sensitively impressed by such objects as gratings, consisting of alternate dark and light parallel lines, whether printed on paper, or made of wirework or drawn on glass. Let the observer place himself at such a distance from the grating that, with the aid of spectacles giving perfect accommodation of the eye, he may just be able to distinguish the bars or lines separately from each other. Then let him place before his eye a card in which fine apertures of different diameters have been pierced, and observe whether he still sees the lines or sees them as well with as without the card. The grating must be brightly illuminated (*e.g.*, by exposing lines printed on paper to direct sunlight), in order that the picture seen through the aperture may remain sufficiently bright. On trying the experiment myself, I find that a notable deterioration of the image is caused by an aperture of 1.72 m.m. diameter, and the deterioration is much more striking with still narrower apertures.

Instead of a series of lines printed letters may be used, the same conditions being fulfilled, namely, by observing the point at such a distance that the single letters may be just distinguished. On looking at them through an aperture of 1 m.m. diameter, they will be scarcely or not at all legible. This experiment is, however, not so sensitive as the first. But, in all cases, the best accommodation of the eye must be carefully maintained, otherwise the act of passing a card, pierced with an aperture, before the eye may, when there is imperfect accommodation, actually improve vision by diminishing the dispersion.

The theory of diffraction of rays in the microscope leads, as will be shewn in the following pages, to the conclusion, that any single point of light in *the object* must, when viewed through the microscope, appear exactly, as if an actual luminous point, situate in the *image of the object* were observed through an aperture corresponding in size and position to the ocular images (at the so called eye spot) of the respective narrowest diaphragm aperture.

Hence it follows, firstly—that diffraction phenomena must be visible when the ocular image has a diameter less than 1·89 m.m., and that the size of the dispersion circle, caused by diffraction, must increase in inverse proportion to the diameter of this ocular aperture, consequently in direct proportion to the amplification, supposing that the incident light from each point in the object remains unchanged. Under such circumstances then, the image will not, even with higher amplifications, suffer *further* loss of sharpness of outline from diffraction, inasmuch as the dispersion circles preserve, throughout, the same relation to the apparent magnitude of the object. On the other hand, the deterioration arising from diminished brightness and multiplication of darker entoptic shadows, must increase with the amplification. From this it follows, therefore, that, as a general rule, that amount of amplification will shew most detail by which the minutest points that are visible at all in the image, shall be presented under the most suitable visual angle, namely, somewhat larger than that at which an

observer can distinguish the minutest objects visible to him under any circumstances.

Calculated by the equation before mentioned, the diameter (1·89 m.m.) of the area of light-rays entering the pupil, when the light incident on the objective (in air) spreads out to nearly 180°, corresponds to an amplification of $264\frac{1}{3}$. For objectives with less aperture the amplification must be set down at a lower figure. In H. v. Mohl's handbook of the microscope it is stated, that amplifications varying between 300 and 400 allow most detail to be seen, whilst Harting, speaking of more recent instruments with large angular aperture, found amplifications of 430 to 450 most serviceable.

If now it be required to determine the magnitude of the minutest recognisable object as a standard by which to measure the accuracy of the microscopic image, we must not take for our unit the measured diameter of such objects as bright single spots or lines on a dark field, or vice versa, for the reasons which I have already given in my handbook of physiological optics (p. 217), in discussing the capacity of the eye for distinct vision. For, in the cases above mentioned the result depends not only on the proportional magnitudes of the images, but also on the susceptibility of the retina to slight differences of light. The most suitable objects are, here also, fine gratings which shew alternate clear and dark stripes. Such indeed are in common use, as in the examples of Nobert's lines, and the line-systems of diatoms and insect scales. But as the light of the bright stripes is doubtless strongly dispersed before it becomes quite undiscernable, dependence can be placed only on the measurement of the space between the centres of two contiguous stripes, and not upon the measurement of space occupied by the stripes (wide or narrow) as originally distributed. I select, therefore, as the measure of the minutest distinguishable objects, that smallest appreciable interspace between the centres of two contiguous stripes by which these stripes can still be recognised as separate.

When diffraction is caused by a fine network of square meshes,

it can be proved that the network must appear as a uniformly illuminated surface when the breadth of fringe of diffracted light is equal to that of the open space of the network. For circular meshes, the integration for calculating the distribution of light is tediously diffuse. When the diameter of a circular mesh is equal to the length of one side of a square mesh, the outmost fringes in the spectrum of a bright spot are of equal width, but the innermost fringes are wider in the circular meshwork. If, therefore, the fringes of the square meshes are so broad as to efface all impression of separate bright lines of the network when the measured widths of fringe and mesh are equal, the same thing must happen with the circular meshwork, a portion of whose diffraction-fringes is still wider. For this reason I have, in the following demonstrations, taken the width of the outermost fringes of a circular meshwork as the lower limit of distinguishable distances in an object. It is not, however, impossible that by some fortuitous overlapping of images, objects of still smaller dimensions might, occasionally, be half seen, half guessed at. But safe and certain recognition will scarcely be possible.

Let now—

ε be the magnitude of the smallest recognisable interspace

λ wave length of the medium,

a divergence angle of the rays incident in that medium,

λ_0 a_0 the values of the last named magnitudes (λ and a) for air,

Then by the formulæ deduced in a subsequent page—

$$\varepsilon = \frac{\lambda}{2 \sin a} = \frac{\lambda_0}{2 \sin a_0}$$

For white light we may, as before, take the wave length of the medium bright rays.

$$\lambda_0 = 0.00055 \text{ mm.}$$

If $a_0 = 90°$ then $\varepsilon = \frac{\lambda_0}{2} = 0{\cdot}000275$ mm. $= \frac{1}{3,636}$ mm. or $\frac{1}{92,000}$ inch.

Were it possible to obtain with an immersion lens, the transmission of rays = 180° of divergence aperture (in water) α would then = 90° and λ nearly $\frac{3}{4}$ λ_0

$$\text{and hence } \varepsilon = \frac{1}{4{,}848} \text{ mm.} = \left(\frac{1}{122{,}000} \text{ inch}\right)$$

According to measurements of Harting (published in vol. 114 of Poggendorf's annals), the magnitude of the smallest distances taken with No 10 objective of Hartnack, reckoned by our formula is

$$\varepsilon = \frac{1}{3{,}313} \text{ mm.}$$

The figures $\frac{1}{3210}$ mm. given by Harting refer to the width of the dark space *between* the lines. In close accordance with the above are the measurements by Herr L. Dippel (in his work on the microscope, Brunswick, 1867), of fine diatoms, who found that the closest series of lines that he could distinguish $=\frac{1}{3500}$ mm., and the finer Nobert lines = $\frac{1}{3800}$ ($\frac{1}{96000}$ inch). Earlier measurements 1853, of Messrs. Sollitt and Harrison (Quarterly Journal Microscopical Society, vol. 5, p. 62) count much higher. Recognisable lines Navicula Arcus are said to have been counted at 5120 to the mm. ($\frac{1}{129000}$ inch). This far exceeds the theoretical limits for objects in air. But since all later measurements remain much lower than these, I do not know that they are trustworthy. Harting, also, who cites them doubts their accuracy.

Besides, any possible further increase of angular aperture in the case of objects lying in water, the capacity of performance might, perhaps, be increased by employing blue rays only.*

In photography, blue light is chiefly active, and photographs appear actually to perform more than the eye can with white light. In a photograph of Surirella gemma, executed by Dr. Stindi, with an objective of Gundlach's, giving $\frac{1000}{1}$ amplification, lines are

* Hartnack makes an illuminating apparatus for use of blue rays only, and exhibited it in the Vienna Exhibition, 1874.

visible which may be counted at 3800 to 4000 in the millimeter ($\frac{1}{100000}$ of English inch.)

Thus it appears to me beyond doubt that diffraction of the rays is the the principle cause of the limitation of sharpness of the microscope image. In comparison with diffraction, chromatic and spherical aberrations appear to exert but an inconsiderable influence, in spite of the very large angles of incidence and divergence of rays. Considering the extreme care expended on calculation and execution of lenses for telescopes and the photograph-camera, it is justly a matter of surprise that with the lenses of the microscope, which are so much more difficult to construct according to prescribed dimensions, and which have so large an aperture, spherical aberration makes itself so little felt. I have, however, already pointed out that when there is water between the object and covering glass, and also between this and the objective, the divergence angle is not 87½°, as usually stated, but only 48½° With dry mounted objects an angle of 87½° can indeed be in action, but *only through the minute distance between the object and covering glass*, so that the spherical aberration arising therefrom is of no importance.

As wide pencils of light are needed to keep diffraction within moderate limits, the illuminating apparatus should also be capable of emitting pencils of the same angle, in order to show clearly the contour lines of dark objects.

If there happen to be particles in the object which act like lenses, these may of course convert a small illuminating pencil of rays into strongly divergent rays, and so become clearly visible. Otherwise nothing is seen but a confusion of diffractions at and in the object on one part, and in the (optical) aperture of the microscope on the other part.

Here lies obviously the explanation why microscopes, otherwise good, but whose illuminating apparatus is not specially arranged for the purpose, yield, with artificial illumination, *e. g.* a flame, such unserviceable images of the outlines of dark objects. For an immersion lens, the best illuminating apparatus is one constructed according to the same principle—that is to say, a lens of the same

kind reversed. The readiest mode of finding whether the illuminating apparatus gives sufficiently wide pencils of light is to examine the ocular image with a magnifying lens after the instrument has been focussed.

I must now relate here the *failure of an attempted improvement*, the negative result of which is significant. I thought myself justified in inferring theoretically, that the diffraction of the microscope might be neutralised if the points of the narrow aperture which causes this diffraction were made singly and separately luminous, and that this could be affected by causing a sharply defined optical image of the source of light, (*e.g.*, sun illumined cloud,) to be thrown by a lens on the plane of this aperture. Years ago I tried experiments of this kind on a Nobert microscope, provided with immersion lenses, giving excellent definition. The result of this trial shewed that it was perfectly indifferent whether the image of the source of light fell on the plane of the object, or of the objective. The diffraction fringes caused by the use of a very deep ocular remained uncorrected. More recently I have convinced myself by fresh trials made with larger lenses, that such a procedure is useless. When a good achromatic lens of about 18 inches focus, is so placed as to show a sharp image of the source of light, (as in this case a bright sky cloud,) upon the surface of a system of lines scratched on glass, the images of many separate luminous points will be thrown upon the variously transparent clefts of this grating, and it might be supposed that the interference of rays which had passed through neighbouring clefts would cease. If however we look through the grating towards the lens, and place before the lens pieces of card pierced with fine slits, we see with the naked eye just the same diffraction fringes, as well at these slits as at the outer edges of the cards, as would be seen if the lens were removed, or the grating set out of focus.

Instead of the lines I then made trial of two fine linear slits cut in cardboad, with an interspace of about one m.m. and through which I could see with the naked eye a system of very fine

interference lines belonging to the diffraction image of another slit which was cut with the lines at a very small acute angle, sufficiently narrow to produce the interference lines at the point of this angle. But these did not disappear when I threw an optical image of the incident light on the plane of the double (parallel) slit. In this experiment not the slightest suspicion could be entertained that chromatic, or spherical aberration had dispersed the rays over an interspace of 1 m.m. width. The only explanation I can offer, is, that the light from the lens which passed through the acute angle of the slit serving here as object, suffers so strong a diffraction that it subsequently reaches the two openings of the doubly-slit card with a corresponding wave-phase and therefore sends interfering bundles through both openings. In order to be able to see the interference lines, it is necessary that their minima shall appear at a wider distance from each other than the width of the lines of which they are images, and when this condition is fulfilled theory does in fact shew that the central clear portion of the diffraction figure of the simple slit forms a line of light which is broader than the distance between the two slits of the doubly-slit card.

Similar relations take place (although more difficult to subject to calculation,) when the fine edge of a dark screen is used as the object. It is known that from such an edge, bundles of interrupted rays (in linear formation) likewise bend themselves into the dark field, which have corresponding phases of movement, and so when bent by a second screen can exhibit regular interference. That the resultant effect cannot become *nil*, appears clearly from the fact that the effect of a bright line may be represented as the product of the action of two endless half-planes bounded by straight lines the edges of which half-planes slightly overlap each other, minus the action of an equally bright whole plane. As the latter causes no interference phenomena, the bright line of itself could not cause interference in any part of the field, unless each of the half-planes also produced such interference. It follows therefore that the light bent away from a straight edge must also spread

itself out with notable strength to the same width as would the light from a slit in the card bounded by two other slits.

THEORY OF DIFFRACTION IN THE MICROSCOPE.

In conclusion I shall here shew a method by which the diffraction of rays passing through the microscope may be theoretically calculated. Instead of the simple lengths of rectilinear rays, as taken into consideration by the theory of diffraction of light which passes through one medium only, the *optical lengths* of the rays must be taken, that is to say, the lengths obtained by adding together the product of each portion of a ray multiplied by the index of refraction of the medium through which it passes.

The wave phases of two rays that have started from the same luminous point, and have equal optical lengths, are also equal at the other terminal point, because the wave lengths in different media are inversely proportional to the refractive indices. Further, it is known* that the optical length of all rays between two conjugate foci of the same pencil in which a perfect re-union of these rays is accomplished is equally great.

In order to calculate the diffraction through the (relatively) narrowest aperture of the microscope, each point (c) in the plane of this aperture must be treated as a ray centre whose phase is determined by the optical length of the normally refracted ray, which, starting from the luminous point (a), has arrived at c. This length I designate with ac. On the other hand, the difference of phase between c and the point b in the surface of the image whose brightness is to be determined depends on the optical length cb found for the normally refracted ray travelling from c to b. The phase of movement continued from a, through c as a new centre of the ray, to b, will, therefore, depend on the sum of the optical lengths $ac + cb$. The share which this ray has in

* The proof of the law here adduced is to be found in my *Handbook of Physiological Optics*, and elsewhere.

the movement in the point b will be given by an expression in the form

$$A \ sin. \left\{ \frac{2\pi}{\lambda} [ac + ab - at] + Const \right\}$$

Where λ is the wave length in empty space, A the speed of progressing movement, t the time. The sum of these quantities taken for every point c of the aperture (in which the factor a can be considered as approximatively independent of c) will finally determine the movement at b.

If now we suppose the rays passing from (a) and (b) to the point (c) of the relatively narrowest aperture to be prolonged in the direction which they have at the point (c) until they intersect each other in the points (α) and (β), these last points will be the images of the points (a) and (b), formed in the medium of (c). Since, then, from what has been said above, the optical lengths ($a\alpha$) and ($b\beta$) being lengths measured between conjugate foci, are constant, we may put

$$(ac) = (a\alpha) - (c\alpha)$$
$$(cb) = (\beta b) - (\beta c)$$

The direction of movement of the ray must be conceived as always advancing from the first to the second letters; and therefore,

$$(c\alpha) \text{ be put } = -(\alpha c) \text{ as also } (\beta c) = -(c\beta)$$

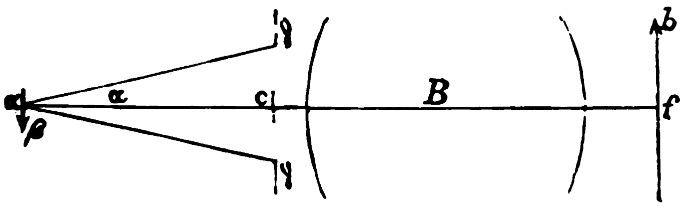
Then the expression for the effect of each separate ray on the point (b) becomes

$$A \ sin. \left\{ \frac{2\pi}{\lambda} \left[(\alpha c) - (\beta c) - \frac{t}{a} + (a\alpha) + (\beta b) \right] + \ Const \right\}$$

The only terms amongst the signs bracketed under the sine that vary with the point c are $(\alpha c) - (\beta c)$. These optical lengths, however, lie wholly in the medium of (c), and are, therefore,

straight lines; consequently, the diffraction effect of the light from (a) at the point (b), apart from the factor A, which expresses its total intensity, will be the same as that of the light from α for the point β. But the latter can be calculated according to the known method valid for rectilinear rays.

Fig. 2.



Let $\gamma\,\gamma'$ be the relatively narrowest aperture, and (o) its middle point, B the portion of the optical system immediately behind this aperture, and let α be the image of the axis point a of the object; further, let $\alpha\,\beta$ be its image lying in the medium $\gamma\,\gamma'$ and $f\,b$ the image formed by B in the last medium.

When light proceeds from α, and is viewed through the aperture $\gamma\,\gamma'$ whose radius is ρ, interference fringes will appear around α, in which the distance δ between each two neighbouring maxima, (excepting the two first) will be according to known laws, if as before, α represents the divergence angle $c\,a\,\gamma$, which by assumption is very small.

$$\delta = \frac{(a\,o)\,\lambda}{2\,\rho} = \frac{1}{2}\;\frac{\lambda}{\alpha}$$

If N be the amplification of the image $b\,f$ in comparison to $\alpha\,\beta$, the breadth of fringe δ' of $b\,f$ will be

$$\delta' = N\,\delta = \tfrac{1}{2}\,N\frac{\lambda}{a} \quad (8)$$

or as $N = \frac{n\ a}{n'\ a'}$ when a' expresses the divergence-angle of the emergent ray, n' the refractive index of the last medium, n that of the medium at (c).

$$\delta' = \frac{n}{2n'} \times \frac{\lambda}{a'} \quad (8^a)$$

If $n = n'$ then the form in which this value of the breadth of fringe of image $b\,f$ is expressed is exactly analogous with that for $a\,\beta$, and shows that the fringes in the last image are of just the same dimensions as if seen through the aperture which determines the divergence-angle a' of the cone of rays $\gamma\ a\ \gamma$ or in other words, through the ocular image of narrowest aperture.

The above demonstration pre-supposes that the relatively narrowest aperture of diaphragm is situate where the divergence angles of the pencil of rays are very small. It may however be situate at any part of the instrument. With an immersion microscope this condition is indeed not fulfilled when the surface of front lens is the relatively narrowest aperture. But it would be fulfilled if the aperture were situate on the upper side of the second or third lens. Thus if there were no lateral outspread of the advancing rays on their passage through the front lens of the objective where the pencil is still diverging strongly, then from the point where the divergence is weak, or convergence commences, its lateral limitation, whether occasioned by a diaphragm actually situate at the place, or only conditioned by the previous course of the rays, must nevertheless produce a diffraction.

As regards the final result, it makes no difference whether the aperture at the circumference of the pencil of rays be supposed to

be situate a little more to the front or to the back. The image of this aperture formed by the ocular lenses will be very slightly larger when it is situate at the back lens than when it lies in the front lens, but the difference is without any practical significance.

In equation (8) δ' is the breadth of fringe in the last image, a the divergence angle in the medium where the aperture lies, λ the wave length at the same place, N the amplification of the last image, as distinguished from that formed by the rays passing the aperture.

If, on the other hand, we put N_1 for the amplification of the last image referring to the object λ_1, and n_1 for the wave length, and refraction index for the medium in which the object lies, we may according to equation (7) make as a is, by assumption, small

$$\frac{n_1}{N_1} \sin. a_1 = \frac{n}{N} \cdot a.$$

a_1 is the divergence angle in the first medium.

Putting the value of $\frac{a}{N}$ in equation (8) it becomes

$$\frac{\delta'}{N_1} = \tfrac{1}{2} \lambda \frac{n}{n_1} \cdot \frac{1}{sin\ a_1} = \varepsilon$$

or, as $\lambda\ n = \lambda_1\ n_1 = \lambda_0\ n_0$, which last refers to air medium, we have

$$\frac{\delta'}{N_1} = \frac{\lambda_1}{2\ sin\ a_1} = \frac{\lambda_0}{2\ sin\ a_0} = \varepsilon$$

This ε is the true magnitude of those lengths in the object, which in the magnified image of the fringes appear equal, and will, therefore, be effaced. Therefore, ε may be considered the measure of the smallest distinguishable distances in the object. ε will be smallest when a_0 is largest,—that is to say, when amounting to a right angle. In that case

$$\varepsilon = \tfrac{1}{2} \lambda_0 \qquad (9)$$

This determination of limit is likewise, as may be seen, independent of the construction of the optical instrument. It holds just as valid for a photographic apparatus as for the relation of the microscope to the eye of the observer. These are the formulæ which were applied in the calculations previously given.

On Aperture and Definition of the Microscope Object Glass.

By DR. H. FRIPP.

SINCE the MSS. of the foregoing translation (completed sixteen months ago) of Professor Helmholtz's essay was sent to the printer, I find that the investigations of Professor Helmholtz have been noticed by Mr. Sorby, in his presidential address to the Royal Microscopical Society.* This gentleman's comment on the "Limit of the Powers of the Microscope" bears mainly upon the conclusions of Professor Helmholtz respecting the influence of diffraction upon the image, formed in the microscope, of very fine and closely ruled lines, and on the limit thereby placed to their separate recognition by the eye. A formula, expressing the physical limits of resolution—*i.e.* the measure of narrowest interspace between two finely drawn lines which admits of the formation of a separate and distinct image of these lines upon the retina—was deduced by Helmholtz, from his mathematical demonstration of the theory of diffraction, as it occurs in the microscope. Mr. Sorby, quoting this formula, employs it for a few calculations, arranged in tabular form, showing the limits of resolution of a series of lines, when

* *Vide Monthly Microscopical Journal*, number for March, 1876.

viewed through a microscope armed with objectives of given angular aperture, under the several conditions of illumination by red, blue, and mean rays of the spectrum. Of course this formula, and all calculations made from it, must exceed any possible actual performance, even on the assumption of perfect construction of lenses and exact fulfilment of the conditions necessary to perfect amplification, definition, and brightness of image. Helmholtz does not apply his formula to measure *distinctness of definition* of points, lines, spaces, or surfaces, but simply to find how closely two lines (or a series of lines) may be approximated before "interference" waves blot out the separate impression of these lines on the retina, and to mark this nearest approach as the measure of extreme limit of resolution.

But Mr. Sorby, in referring to his table, says :—"The examination of this table will clearly show the value of aperture in 'defining' lines at very small intervals on flat objects like diatomaceæ, though in practice the advantage may be entirely counterbalanced by other (?) disadvantages in the case of a different class of objects."

The readers of Professor Helmholtz's essay will scarcely acquiesce in the correctness of a statement which attributes increase of "definition" to larger angular aperture, unless the term "definition" be understood in a more liberal than literal sense, as meaning *freedom from diffraction effects.* But it must be borne in mind that diffraction phenomena in the microscope arise from two distinct sources, and affect the microscope image in two very different ways. The diffraction which is occasioned when a brightly illumined image is viewed through a small optical aperture (and such is the case in the microscope) annuls, by interference of wave undulations, the vision of very minute objects, or produces false images by distortion. There is here no question of "definition," but of seeing or not seeing, and, *if seen*, of true or false representation. It is a question of "resolving" or not "resolving" the object. The second mode in which diffraction affects the microscope image is when, from some peculiarity in the object, e.g., structural particles or finely ruled lines, &c., some illuminating rays are split

into small divergent diffraction pencils, which, entering a wide angled objective, form "positive" images (with, perhaps, coloured fringes) of the particles or lines which caused the diffraction. These images are "positive" because they repeat the self-luminous character which marks their peculiar mode of origin. But, though delineated in accordance with dioptric law, they differ from the "negative" images formed by non-diffracted rays (that is to say, by the ordinary pencils of light) in one important respect, namely, that, owing to the greater dispersion of such diffracted pencils before reaching the objective, a large aperture only can admit them, and the diffracted pencils which form these positive images have, therefore, a greater inclination to the axis.

If now "definition" be interpreted to mean accurate geometric delineation of a microscope image, it is manifest that the source of "definition" is *not* "angular aperture" of an objective, but accurate *focussing function* of a lens or system of lenses. And, so far as concerns the diffraction images admitted in virtue of large aperture, they may be a cause of *deterioration* of the general effect, unless the spherical aberration of rays having an extreme inclination to the axis of the instrument, be so corrected that the focussing function shall bring the diffraction images into perfect correspondence with the negative images formed at the same moment. And again, as respects the diffraction effect caused by the minuteness of optical aperture of the whole system of lenses of the compound microscope (including the ocular), through which the final image is viewed by the eye, the good effect of large "aperture" of objective is also *contingent* upon the perfection of its focussing function, that is to say, *depends upon good definition instead of being the cause of it.*

The view here briefly expressed accords strictly with the observations of Professor Helmholtz, and the researches of Professor Abbe, and I propose, as the subject is not without interest at the present moment, to discuss it a little more fully in the following pages.

In the first place Helmholtz has himself, in the first part of his essay, indicated the true nature of definition by showing its dependence on the aperture, *not* of the objective, but of the illuminating

cone of light beneath the object. The angular divergence of the pencils issuing from the object and incident upon the objective being regulated by that of the illuminating cone, every one who uses a diaphragm between the mirror of his instrument and the object on its stage (or any arrangement employed for the same purpose) practically recognises and acts upon the fact (whether understood or not) that delineation of the microscope image is best regulated by comparative trial of the different sized openings in the diaphragm. Or, in other words, by suiting the angular divergence of the defining pencils—it is the light which defines – to the capacity of the lens used. And a very little experience suffices to show that the effect of a larger or smaller illuminating cone stands in direct relation with the magnifying power used. With low and moderate powers, the best "absorption" or "negative" image is obtained by using the diaphragm to shut off light, *i.e.* by *reducing* the divergence of the defining pencils, which thus enter the objective with less inclination to the axis and form sharp points instead of "dispersion circles." With higher and highest powers the divergence of defining pencils may be extended until nearly the full aperture of the objective is occupied, but definition becomes more and more critical. In the first half of Helmholtz's essay the relation of illuminating cone to amplification and brightness of image is fully demonstrated, and it is shown that no diffraction effects occur until the optical aperture through which the image is viewed becomes smaller than the aperture of the pupil, but that they increase at an enormous rate as the magnifying power is increased.

In the next place Professor Helmholtz, in dealing with the question of extreme limits of resolution, obtains from his theory of diffraction the formula $\varepsilon = \dfrac{\lambda_0}{2 \sin \alpha}$. He does not, however, apply it as expressing any value of "defining" power of aperture, but simply as *expressing a certain relation between the wave length of the different colors of the spectrum, and the aperture of an objective* by which the smallest interspace between finely drawn lines

which shall allow these lines to be separately visible to the eye may be computed.*

And he himself gives the following arithmetical calculation in accordance with his formula:—Taking ·00055 mm. ($=\frac{1}{1818}$ mm.) as the wave length of medium rays, and 90° as angular divergence of a dry lens (or a lens constructed on immersion principle used dry), and assuming perfect correction and adjustment of lens and instrument, then $\frac{1}{1818} \div 2 = \frac{1}{3636}$ mm. (or $\frac{1}{92000}$ inch).

This is the same calculation and gives the same result as that in Mr. Sorby's table for mean rays and 180° aperture (twice the divergence angle).

Helmholtz next points out that if the rays could be transmitted through water with the same divergence as through air, then the wave length λ would be $\cdot 00055 \times \frac{3}{4} = \cdot 0004125 = \frac{1}{2424}$ mm. And α being supposed $= 90°$, it follows that $\varepsilon = \frac{1}{2424} \div 2 = \frac{1}{4848}$ mm. or $\frac{1}{122000}$ inch.

The extreme limit of minuteness is then shown to be *dependent on the wave length of illuminating rays.* And this appears more distinctly from the calculation when blue rays are employed whose wave length $= \cdot 0004282$, as ε is then $= \frac{1}{4670}$ mm. or $\frac{1}{118000}$ inch, with the immersion lens *as at present used.*

The figures in Mr. Sorby's table show (what has, however, been long known), firstly, that red light is the worst for rendering minute objects visible, whilst blue, if collected in sufficient quality to supply brightness of image as well as to bear high amplifications, would be best. This inference is, indeed, sufficiently justified by the known differences of susceptibility of the retinal nerves to colour (i.e., for undulations of such widely different wave lengths as those of red and blue), and by the different course of these rays

* The *same formula* and the *same explanation* of it is given by Professor Abbe, in ¶ xix. of his essay (page 244 this vol.), namely, that it expresses the extreme limit of separable objects—so far as *seeing* is concerned. But this theoretically possible "resolution" becomes an actual one, only when the essential conditions of definition—accurate focussing function and regulated angle of illuminating pencils—are also properly fulfilled.

through the dioptric media of the eye.* But secondly, the table shows that increase of aperture is not so efficient in resolving the extreme minute lines or spaces when the aperture is increased beyond 110° as when it is being raised from a comparatively low figure up to this degree. Neither is "*variation of defining power with the chord of the angle of aperture*" (J. Hogg†) to be understood as one of progressive excellence due to increase of aperture, nor, indeed, is this use of the term *defining power* "in absolute agreement with" any teaching of Helmholtz concerning definition, or with any theory of diffraction phenomena which interfere with the vision of closely ruled lines. This appears even from Mr. Sorby's own table, calculated from the formula given by Helmholtz. For, if the figures in this table (copied from the Monthly Microscopic Journal, for March),

	60°	97°	120°	150°	180°
Red End of Spectrum ...	$\frac{1}{37000}$	$\frac{1}{55000}$	$\frac{1}{64000}$	$\frac{1}{71000}$	$\frac{1}{74000}$
Mean Rays	$\frac{1}{46000}$	$\frac{1}{69000}$	$\frac{1}{80000}$	$\frac{1}{89000}$	$\frac{1}{92000}$
Blue End	$\frac{1}{60000}$	$\frac{1}{90000}$	$\frac{1}{104000}$	$\frac{1}{116000}$	$\frac{1}{120000}$

* This difference in discrimination of colour by different parts of the retina is a normal one, but is not evident when white light is used because the middle rays greatly predominate. The difference reaches its climax in persons who are colour blind, the commonest form of which is red blindness, when red colour (and the red end of the spectrum) cannot be seen at all. The hypothesis of Dr. Young is accepted by Helmholtz, viz., that one kind of nerve when excited by the longest undulations induces a sensation of red light, a second nerve excited by medium undulations induces green light, and a third nerve excited by the shortest undulations conveys impression of violet. The latest anatomical researches tend to show that a triple strand of this kind forms the rather thick nerve which connects the *cones* with the ganglionic layers of the retina.

† See Mr. Sorby's address (loc. cit.), page 110, line 12.

be compared as they stand in each column, one fraction under the other, they clearly prove that the number of distinguishable lines and interspaces (or, as Mr. Sorby puts it, the number of lines "defined" at very small intervals) *varies as the wave length of the colour* with the *same angle of aperture.* And this would be true of all the colours of the spectrum. Taking the extremes and means as here given, the variation of *what is called* "defining" power is as 1 : 1·63 *for the same aperture.*

Or again, if the fractions in the two columns, headed respectively 97° and 180° (a difference of more than 80°), be compared, we find that the *lens of* 97° *aperture*, with blue rays, "defines"—supposing, with Mr. Sorby, that his table "clearly shews the value of a large aperture in defining"—*as well as the lens of* 180° *aperture* with white light.

But it may perhaps be said that when the figures are read in line instead of column they *do* show increase of defining power with increase of aperture. Yet, on nearer consideration, it will be found that the denominators of the fractions denoting approach to extreme limits of "definition," although rising to a higher figure, actually indicate a diminishing rate of increase. If, for instance, the "defining" power of an objective of 60° aperture be called 1, then the difference of increased "defining" power of an objective of 90° aperture is — compared with the first — as 1·5 : 1. But the rate of defining power of an objective of 120° aperture to that of the objective of 90° is only as 1·16 : 1. And the rate of defining power of an objective of 150° aperture to that of the objective of 120° is only as 1·1125 : 1. Lastly, the ratio of "defining" power of the objective of 180° to that of an objective of 150° is only as 1·0337 : 1. From this it is clear that a few degrees of aperture beyond 110° cannot give any appreciable increase of value *when the effect of a rise of* 30° *at a time is so little.* And this too, in spite of the fact that every 30° of additional aperture, gives a largely increasing zone of marginal light. But, while the figures of this table fail to prove the value of large aperture in "defining," they indicate still less respecting the

amount and quality of light admitted by larger aperture, and they ignore a circumstance which really is, and should be considered, the master condition of the problem, namely, accompanying increase of magnifying power, because angular aperture is a necessary accompaniment of the construction by which increase of magnifying power is obtained (increase of curvature and shortening of focal length of the lens). Now the definition of the more magnified image may or may not be improved, but if only *not deteriorated* the additional amplification cannot but further separate and thus render visible (resolve) lines that were too close to be seen separately with a glass of smaller aperture and lower power.

The fractions in the table indicate that separation of detail progresses in a marked manner with increase of angle up to 100° or 110°. And this range of increased aperture corresponds with the deepening curves of construction of a lens by which its magnifying power is raised. But, beyond the amplification suited to an aperture of 110° (in an objective made to be used "dry"), the resolution of lines separated by clear interspaces is obtained with greater difficulty, because the additional magnifying power spreads the light over a larger image, whilst that image must be viewed through a smaller optical aperture. As soon as light and shade are less contrasted, sharpness of vision fails. And, with high power lenses, diffraction effects are unavoidable if the illumination be intense. Thus the limits of physiological vision are being approached in two ways—first, by faintness of marking if the brightness of image fails; and secondly, by indistinctness of outline from overlapping images or blurring by interference waves. The faculty of visual analysis is weakened or destroyed before the theoretical limit (half the wave length of violet rays) is reached.

Now, it is known that definition is improved in all low and moderate amplifications by use of diaphragm openings, which regulate and reduce the angular spread of the incident defining pencils of light. But this narrowing of illuminating pencils necessarily favours diffraction, whilst wide pencils (i.e., larger

angles of incidence) moderate diffraction. "Definition," therefore, instead of improving "with the chord of the aperture," depends rather upon a compromise between magnifying power and aperture which shall give the greatest brightness of image, compatible with good focussing function and least diffraction. The first and most important condition under which it is possible to maintain good definition is the counteraction of that spherical aberration which increases with power and aperture of a lens-system, by the proper calculation of curves and refraction of its constituent parts, and compensation for residual aberrations. And the difficulty of construction and compensation is increased with every addition to aperture beyond 110°*.

That the physical limit of resolution, computed from any formula based on such assumed perfection of the microscope as is needed to realise every theoretical possibility, must be in excess of what the eye itself can perform, will be obvious to all who have studied physiological optics. A few observations on this part of the subject will be appended to the present paper, but attention may here be directed to the fact that far more minute details may be delineated in a photograph than on the retina. Undulations of shorter wave length than will affect the retinal nerves can act powerfully upon photograph materials, so that chemical rays delineate lines too closely approximate for the eye to distinguish when looking at the same object through the same objective. Here then the resolution is entirely physical, and the *physiological limit of eye performance is surpassed*. This fact is indeed but an extension of the principle that "resolution" is associated with the different wave length of

* It is true that lenses of equal magnifying power, but different aperture, perform very unequally, and that definition will often be best in the image formed by the objective of larger angular aperture (excepting cases of extreme angle), provided that correction of spherical aberration be perfect for those parts of the objective through which pencils of large divergence angle pass, so that their points shall not become dispersion circles. But mere aperture, without suitable construction, confers no defining power. In Professor Helmholtz's essay the mathematical demonstration is based on the assumption of a perfectly constructed *immersion* lens, where, as Abbe has conclusively shewn, the correction of spherical aberration is not attended with such difficulties as is the case with large angled "dry" objectives.

different rays of the spectrum, as pointed out already in connection with Mr. Sorby's table. It serves, moreover, to shew that the focussing function by which the photographic picture is delineated must be the really important instrument of definition, for the *amplification* of the microscope-image by chemical rays acting on a photographic plate is *greater* (as 3 : 2) than when seen by the eye*.

But the total inadequacy of the dictum that "defining power varies with the chord of aperture" should appear from the very obvious fact that the definition of a modern camera lens or telescope object-glass is more perfect with less angular aperture than belongs to microscope objectives of even low power. Or, if this dictum be intended to apply only to the microscope image, it remains to be shewn how it may consist with the fact that the objective of say 120° of aperture, made fifteen years ago, does not equal in performance the objective of *same aperture* made now, or with the fact that an immersion lens of smaller angle surpasses the definition of a dry lens of greater aperture; or again, with the fact that lenses having the same angular aperture, but constructed by different makers on different lines—nay, even when made by the same optician, and on the same principles—vary in "defining" power according to the illumination and to the kind of object.

Does not such a dictum (it were not worth while to disprove it but for the prevalence of an error which might be traditionally perpetuated amongst other myths appertaining to the history of the microscope) ignore too much, and take too much for granted? Does it not ignore the defects which excessive aperture introduces? Does it not assume that difficulties of the optician are all solved for him by angular aperture? Has it not driven the optician himself against his better knowledge and experience into a struggle for a few more degrees of aperture, and filled the purchaser with a delusion that an objective is cheap at any price which has these few additional degrees of aperture?

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* See page 245 of this vol., Abbe on the Theory of the Microscope.

A better understanding of the part played by aperture in defining (as distinguished from *resolving*) microscopic objects may be gathered from the essays of Helmholtz and Abbe, translations of which have been given in the preceding pages, than from any misapplication of a formula intended only as a mathematical expression of the possible limits of resolution. The readers of these essays will have seen that to each of these terms, long naturalised in micrography, and supposed to convey a separate and distinct meaning, a specific function answering to specific physical phenomena may be truly assigned. In this, as in other scientific enquiries, all depends on a clear and accurate definition of the terms employed, especially when such terms are intended to convey some explanation of complex phenomena and combined effects. For to such combined effect, the reference made by Mr. Sorby in the passage before quoted from his presidential address, was, doubtless, intended to apply. But it seems a pity to endanger the most instructive results of modern research—the fruit of much profound labour—by any loose application of a single term to cover all the physical phenomena concerned in the formation of a well defined optical image. The foundation of the whole series of phenomena which have to be analysed in a theory of the microscope is that dioptric law governing the focussing and magnifying functions, which obtains equally in every objective whatever be its angular aperture; and "definition" depends alike in small or large angled objectives upon correction of spherical aberration. Increase of angle beyond 110° only throws difficulties in the way of the optician as regards the maintenance of even moderately perfect definition.

For the oblique incidence of the outermost pencils—the prime cause of spherical aberration—is the main characteristic of large aperture. And the possib le gain of defining pencils of large divergence angle, as well as the possible addition of new details admitted with diffraction pencils (from the object) through the wide angled aperture, will be realised only in proportion to the dioptric perfection of focussing function. In respect to "resolving"

capacity, of which "aperture" may be considered in a certain sense the measure, we have learnt from Helmholtz and Abbe that the deterioration of image, caused by diffraction effects upon the eye looking through a minute optical aperture at a highly amplified image, is lessened by a relatively larger angle of incident defining pencils, and by other circumstances to be mentioned presently. But the formula of Helmholtz, illustrated in Mr. Sorby's table, shews us how greatly the limits of resolution vary with wave length of colour*. The careful study of the optician in producing an "achromatic" objective is so to equilibriate the extreme red and violet images as to give a colourless image in some intermediate focal plane by counteraction of and compensation for aberrant rays. In remedying these defects of dispersion and deviation, as also in perfecting the amplification needful for resolution of minute objects, the operation of angular aperture is *passive* only, whilst the co-operation of every dioptric condition on which their correction depends, must be active. Hence, therefore, the dictum that "defining power varies with chord (!) of aperture," besides leaving everything to be explained, is a most incorrect summary of facts.

When it is considered that the microscope image is literally delineated in points of light from innumerable pencils, each one of which must touch the focal plane at its proper relative distance from the axis around which the image is formed†, it is manifest that

* And also how greatly chromatic dispersion interferes with clearness of resolution.

† The translation of the fundamental law, formularized by Professor Abbe (see page 211 of this vol.), together with the sentence preceding it, having been incorrectly printed from the MSS., we repeat it here as corrected. "The study of these aperture images leads to various conclusions, the full development of which depends on a principle capable of general demonstration, and which may be formularized as a law applicable to every part of the theory of the microscope in the terms following":—

"*When a system of lenses is perfectly aplanatic for one of its focal planes, every ray proceeding from that focus strikes the plane of its conjugate focus at some point whose linear distance from the axis is equal to the product of the equivalent focal length of the system and the sine of the angle which that ray forms with the axis.*"

On this law of focussing function depends the geometrical delineation of the microscope image, whose amplification is likewise herein indicated as depending on focal length and angular aperture of a lens system.

perfect freedom from spherical aberration must be the first and principal condition of accurate definition, and the existence of dispersion circles in place of pointed pencils constitutes the greatest fault of the image forming process.

The conditions under which every objective, whether of large or small aperture, must perform its focussing function are contained in the law demonstrated by Professors Helmholtz and Abbe. In order to see in what respects definition is improved, or otherwise, by additional aperture, it is necessary to determine in what respects the objective of larger aperture differs in its mode of action from an objective of small angle, and how this mode of action affects the dioptric conditions of the focussing function. Now it appears, 1, that the objective of wide aperture admits larger divergent pencils than the smaller angled lens; 2, that, of these larger pencils, such as occupy the peripheral (marginal) zones of the front lens, have a greater inclination to the axis of the instrument than any pencils incident on the lens of narrow aperture; 3, that these outer zones admit not only larger pencils of light, according to the angle of illuminating cone under the object, but also any rays split up by diffraction due to the action of particles in the object, &c., which fall within reach of the aperture of objective. These three points of difference indicate corresponding differences in the conditions of focussing function in large and small angled objectives respectively. In respect to the first (which has a direct bearing upon the theory of diffraction in the microscope) the differences of divergence-angle of the defining pencils of light which enter the narrow or wide aperture of objective, affect, in directly opposite ways, the definition of the image, and the diffraction effect of this image on the eye. Definition is best with *narrow* pencils *up to a certain point*, namely, that at which the narrow illuminating cone being focussed in the optical aperture above the eye piece becomes so small in relation to the magnified image and to the pupil of the eye that diffraction effects begin to appear. From this point, any increase of intensity of light of the narrow pencils increases diffraction; but larger incidence angles of illuminating pencils moderate diffraction. It

is, however, clear that aperture is not *alone* concerned in affecting the minimum of diffraction with maximum definition, since the result depends also upon the relative amplification of image (magnifying power), the size of detail in the object, and the nature of illumination, i.e. kind of light, and whether central or oblique illumination. Nevertheless, *cæteris paribus* wider angle offers a wider range of manipulation and effect to the practised microscopist.

In respect to the second point, the greater inclination of pencils to the axis, the advantage arising therefrom lies chiefly in the power of varying the illumination. The widest cone of light that can enter an objective is that whose point lies on the object exactly in the centre of the axis of the instrument, and whose divergence just fills the available aperture. This cone (above the object) requires that the illuminating cone below the object should be of equal size, and the regulation is best effected for each separate objective by diaphragm and illuminating lens system. Such a mass of light collected equally from all sides must of course yield the utmost quantity that can be obtained, and is, therefore, needed to give brightness to the wide spread image of an object magnified by the highest powers. If there be no chromatic dispersion (which, as well as spherical aberration, is a defect inherent in large aperture), this wide cone of light, entering with relatively wide divergence angle, tends to moderate the diffraction associated with highly magnified images. But, excepting cases of enormous amplification, this absolute maximum of light defines badly, because the bright images formed by pencils passing through every part of the periphery of aperture pour from all sides such a flood of light upon each other as to lessen the delineation by the darker outlines of the absorption (negative) picture. Besides which the general brightness of the field fatigues the retina and also occasions entoptic shadows.

On the other hand, if this central illumination be shut off on one side, or a central stop used with it, a lateral or peripheral illumination with partial or entirely dark field offers the opportunity

of observing many useful effects, particularly when "positive" images only are formed. But the more usual form of oblique illumination, by placing the mirror out of axis, tests to a greater extent the advantage of large aperture in all cases where the object to be resolved contains very minute structural elements, especially when arranged in equidistant lines or points placed either in parallel position or at particular angles to each other. The effect of this oblique illumination is directly proportionate to the amount of inclination of image-forming pencils to the axis of the microscope, and, of course, as only one side of the marginal zone of front lens is in operation, and, therefore, fewer images are formed, there is less overlapping and confusion of outlines.

In respect to the third point—the admission of pencils of light diffracted in passing through the object—large aperture is so essential that it may be said to add (or at least to permit) an entirely new function to the objective. According to Professor Abbe the capacity of "resolving" all minute details is dependent upon the formation of "positive" images by the combination of two or more diffraction pencils, caused by structural peculiarities of the object. These diffraction pencils enter the objective in virtue of its large aperture, and form a diffraction image (or positive image) independently of the absorption image (or negative image), which latter is formed according to the dioptric law by which homocentric pencils proceeding from a focal point are re-united in its conjugate focal point.

But neither is the negative nor the positive image formed with large pencils filling the whole front of the lens system. Each passes independently through different zones of the lens, and changes its position as the illumination is changed. Unless they fall together on the same focal plane, and are accurately superimposed, these negative and positive images will appear in front of, or behind, or beside, each other, and, therefore, the "resolving" power does not *necessarily* become additional "defining" power. Again, the definition of each image may not be much deteriorated by faulty focussing function or colour dispersion—when the pencils

are not large so that their points do not suffer much dispersion—yet, still the combined effect will be marred in proportion as the object is not uniformly free from spherical aberration over the whole area of aperture.

Again, objectives may be constructed with wide aperture, and the focussing of the most inclined pencils be effected with sufficient accuracy, whilst the central zones are left very deficient and incapable of correction. The "definition" of such objectives will be poor even for the particular class of objects for which wide aperture is needed, whilst their definition for ordinary objects will be worse than in good glasses of narrower aperture. This case is far from rare.

Thus then mere aperture is not decisive of the value of an objective, and the struggle for a few degrees of extra aperture may often prove absolutely injurious to definition. It may, indeed, be possible to correct the defects and surmount all difficulties attendant on the use of largest possible aperture even in dry objectives, but to estimate objectives by mere comparison of their respective apertures is as useless as to deny, on the same grounds, the proved excellence of objectives of moderate aperture (100°) which can and do combine resolving and defining capacity commensurate with high magnifying power. Lastly, it appears that the highest resolving power associated with largest aperture is of value only for a special class of objects, namely, such as consist of finely ruled artificial lines, networks with transparent interspaces, or such as contain in their substance, otherwise homogeneous and transparent, minute particles of differing refractive power which cause diffraction. But all such objects, when employed as *tests* for resolving power, fail to exhibit the general and more useful qualities of objectives constructed to define as accurately as may be in one picture (with each fresh focal adjustment) elements of variously irregular figure and light-absorbing power situate in focal planes of varying depths where a resolving capacity of $\frac{1}{80000}$ inch would not penetrate. Even in the case of particles held in suspension in a more or less transparent fluid, the best combination of resolving and defining capacity would avail far more than extreme resolving power which might suggest some indefinable reality.

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On the Physiological Limits of Microscopic Vision.

By DR. FRIPP.

THERE is yet another aspect of this subject which, though seldom studied in connection with the microscope, is of more significance in estimating the limits of vision than lens aperture; namely, the dioptric performance of the eye, and the capacity of the retina to receive and transmit impressions of light.

In Mr. Sorby's address, to which reference has been made in the preceding pages, the "physiological part of the question" is dismissed in a sentence because Mr. Sorby "does not believe *that the ultimate limit of distinct vision would be found to depend on the constitution of the eye.*" And he seems the more confirmed in this opinion by the inference which he draws from certain experiments made by Dr. Pigott that "*the eye could distinguish with a high magnifying power a much smaller interval than the physical properties of light will permit.*" Mr. Sorby further adds (in reference to Dr. Pigott's estimate of $\frac{1}{150000}$ to $\frac{1}{200000}$ of an inch as the limit of visibility,) "*This (?), however, is not what appears to be the most important character of light in limiting the power of the*

microscope for separating lines so near together that they may be obscured, or their number falsified, by interference fringes."

The "*physiological part of the question*" has, nevertheless, been always considered by astronomers, mathematicians, and physiologists to be an essential part of the theory of vision, whether by the naked eye, or with the aid of optical instruments. All that relates to the distinguishing power of the eye, all that we know of magnifying power, all our outward experiences of light, colour, form, size, distance, direction, proportion, and perspective are gained through the sense of sight. And it is impossible to understand the physical characters of light without considering how far they are dependent upon and related to the action of the instrument through which we become acquainted with them. I confess myself unable to comprehend to what "important character of light," allusion is made by Mr. Sorby, as "limiting the power of the microscope for separating lines," &c. If it is merely intended to convey the idea that the effects of diffraction tend to limit the power of the microscope before the full advantages of magnifying power are obtained, the question certainly merits full consideration, and indeed has been already fully discussed in the papers of Helmholtz and Abbe.

But if it be thereby meant that the eye can distinguish the three-millionth of an inch, or the $\frac{1}{3000000}$, or even $\frac{1}{1500000}$, of an inch with the microscope, *because* when, unarmed, the eye "distinctly appreciates" a visual angle of six seconds, and that consequently when aided by high magnifying power the "constitution of the eye" renders it capable of a *defining* power which is only limited by the intervention of certain "physical characters of light," such an inference can, as it seems to me, only be arrived at by ignoring entirely the study of the dioptrics of the eye. For in the eye, as an optical apparatus, the distinction between *acuteness* of vision and *clearness* of vision covers the same ground as the discussion of "resolving" and "defining" powers of an artificial lens-system. Spherical aberration and chromatic dispersion are alike concerned in the image-forming process of eye and microscope. But the

dioptric function of the eye is further impeded by circumstances which do not occur, or if they occur can be better remedied in the achromatic lens-combination of the optician. For instance, animal tissues and fluids are inferior in translucency, homogeneity, refracting, and dispersing power to the materials of which an objective is made; opaque particles fixed or floating in the eye-structures occasion shadows; diffraction spectra of the crystalline lens and shadows of the retinal blood vessels obscure the field of vision. And these difficulties which, as will be shewn in the following pages, are neither few nor unimportant, are inherent in the constitution of the eye; whilst the only circumstances which favour the accuracy of images are (first), that the plan of anatomical construction admits of accommodation of lens to varying focal distance and of movement of the eye on its axes; (secondly), that the eye reduces the image instead of magnifying.

We may, in the first place, consider the question of visual angles and magnitudes. Mr. Sorby quotes an experiment of Dr. Pigott's, by which this gentleman determined a datum of six seconds, from which a magnifying power is inferred when a microscope of $\frac{1000}{1}$ power is used, and this magnifying power is considered as indicating what the distinguishing power of the retina might be if not obstructed by diffractive effects.

Now, assuming the physiological value of the acuteness of vision to be an angular distance, it should not be forgotten that this smallest angle is *determined by the illumination.* "To illuminated points on a dark ground there are scarcely any boundaries. Small as such a point may be, its image has, on account of the *imperfection of the dioptric system of the eye*, a certain extent; and the only question is whether this produces on one or more percipient elements of the retina a sufficiently distinct impression of light to be perceived. Small dark points disappear, on the contrary, very rapidly through irradiation on a bright ground, which lessens the contrast of illumination of percipient elements, and, if the illumination be strong, the contrast will be much less perceptible. The question as to the smallest angle under

which any object is still to be seen is thus *governed completely by the degree of illumination*, and in a physiological point of view it has, therefore, no meaning. *It is a very different thing to determine the influence of illumination on the indistinctness of objects.* Nor is the investigation with a definite illumination devoid of importance in a practical point of view (microscopical investigation), from which view Harting especially has worked it."*

The facts quoted in the note conclusively show the inutility of attempting to determine "limits of visibility" by calculation

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* See *Donders* on Anomalies of Accommodation and Refraction of the Eye, translated for Sydenham Society by Dr. Moore, 1864, page 195.

Dr. Pigott's estimation of visual angle (for his own eye) is cited without any explanation of the various conditions which affect such observations. The experiments of Hueck show:—1. That a normal eye, capable of accommodating itself to near and distinct objects, finds small objects, whether near or far off, disappear at the same visual angle. (N.B.—The comparison being made under same conditions of illumination and by the same eye). 2. That a *line* is seen further off than a *point*, though both may have the same thickness. 3. *White* objects on a *dark* ground are seen at a greater distance than *black* objects on *white* ground. 4. At great distances the necessary visual angle for recognition of objects slightly and gradually increases. 5. The smallest visual angle at which white *points* on black ground were visible was 2′·6, whilst white *lines* on black ground were seen with an angle of 1′·2. A cobweb thread with an angle of 0′·6, and a white hot wire at 0′·2.

Volkmann found that he could distinctly see a hair ·002′ diameter placed 30″ distance. This gave ·000033 inch for the dimension of its retinal image according to his calculations. But he considered such observations unsuited to determine the size of the smallest retinal images which could excite the sensation of vision, firstly, because dispersion of light (from spherical aberration of the crystalline lens) might affect a larger retinal surface than would correspond to the calculated dimensions of the image; and secondly, because irradiation of the stimulus of light would likewise spread beyond the precise area to which that stimulus was applied. And the following experiment appears to shew that one at least of these two circumstances really occurs:—Two parallel cobweb threads being set up with an interspace between them of 0·0052″, Volkmann recognised them as double threads at 7″ distance but not further. But a friend who possessed acuter vision recognised the double threads at 13″ distance. The dimensions of the respective retinal images Volkmann calculated, for his own short-sighted eye, at 0·00037″, and for that of his friend at 0·00021″. But by another experiment (two threads 0·016″ apart, seen at 27″ with aid of spectacles) Volkmann determined the dimension of retinal image, appreciable by his own eye, at 0.00029″. From a comparison of the figures in the two experiments he concludes that the smallest magnitude which his eye could recognise was ten times greater than the smallest recognisable retinal image, and that the focus which his eye could form at suitable distance of vision occupied a space of 0·00029″, and lastly, that the reason why he could not see an object under any minuter visual angle was because the light would then be too much dispersed.

from visual angles of minute objects. For we see that even in normal vision with the naked eye the retinal images are falsified by dispersion of the light passing through the eye structures, and by indistinctness of retinal perception, consequent upon defective delineation of image and insufficient contrast of light and shadow. But if little value can be placed on calculations of actual, from apparent, magnitudes of the visual angles of minute objects, what is to be thought of the assumption that a visual angle, obtained by observing an object with the naked eye and under normal conditions of vision, can be made the basis of calculation of a magnitude obtained by looking through a microscope magnifying 1000 times, without supposing the calculation to be affected by the widely altered conditions of vision, and by a wholly different mode of illumination? Even the magnifying power taken for granted as due to the microscope, (say $\frac{1000}{1}$), is a *compound effect* of the eye and the instrument, the retinal image being about 16 times less than the image presented to the eye and supposed to be seen at the "distance of clear vision" (10 inches). And we have already seen that acuteness of vision does not depend upon magnifying power further than is necessary to separate two objects from each other sufficiently to be capable of giving separate impressions, and this distance is clearly governed by the *distinguishing capacity of the retina*. So again distinctness of image is dependent on accurate dioptric function of the eye equally with that of the microscope. Lastly, in regard to diffraction, which indeed has been proved to exert a potent influence on the microscope image *as seen by the eye*, it must be borne in mind that this diffraction is not produced by any faulty quality of a lens-system, but is the simple consequence of the optical arrangement necessary to bring an enlarged image before the eye, because such arrangement necessarily implies "angular amplification," whereby the whole mass of light, by which the image is delineated, is presented to the eye in a concentrated form, and reduced sectional area, in front of the pupil. Professors Helmholtz and Abbe have insisted on the circumstance that diffraction in the microscope is caused by the narrowness of

opening through which a strong light is viewed, the effect being the same whether produced by a pin hole in a card or by a minute optical aperture of very highly magnifying lenses, combined or not with deep oculars. The diffraction then which limits the resolution of objects in the microscope is a physiological effect attendant upon conditions which do not occur in the ordinary use of the eye, but which, whenever they do occur, are the source of obstruction not to the performance of the microscope, but to the function of vision. For it is evident that a phenomenon which is as readily produced by a pin hole in a card, or by various other physical means, as by looking through a microscope, cannot be attributed to faulty "definition" or "colour dispersion" of this instrument, but that it appertains to the general conditions of vision exercised under circumstances unfavourable to the dioptric performance of the eye as an optical instrument. Whatever, therefore, may be the limit of its performance, it must be sought in the retina or in the dioptric media of the eye. Supposing the microscope picture to be well delineated by a lens of as perfect construction as can be made, the delineating pencils of light which pass out of the microscope in a concentrated bundle of intensely bright rays would, if thrown upon a sensitive chemical preparation, form a well resolved image. But if thrown upon the front of the eye, this bundle of image-forming rays has to undergo a fresh series of refractions and reflections, and the assumption that nothing is thereby changed is not consonant with our present experience. We are not justified in assuming that the eye as an optical instrument does, or does not, deteriorate the performance of the microscope (separately considered), or that, on the other hand, the eye, armed with the microscope, would be capable of greatly superior performance but for restricting conditions placed thereon by certain physical qualities of light. For we must not forget that light itself is but a sensation of the eye, and the physical qualities of light but arbitrary expressions of particular effects which ether-undulations produce on the organ of sight. And it certainly appears most conformable with physiological fact and law, to believe that the sense of sight is neither more nor less subtle than the dis-

tinguishing capacity of the retina, where the conversion of physical impression into special sensation takes place; and that the capacity of the retina for transferring its sensations (or, perhaps, still only modified physical impressions) to the brain, stands in exact proportion to the subtlety of impression which it has received through the separate elements of the retinal layer of *rods* and *cones*. Further, we should expect to find that the dioptric performance of the structures of the eye in front of the retina was just as accurately adapted to the capacity of the retina for receiving separate impressions, yet not beyond it. But, as there appears no *a priori* reason why the sense of sight should exceed in potential subtlety the limits of any possible act of seeing, or the capacity of the apparatus on which the sense depends, so there seems no ground to attribute the limit of visibility to any antagonistic "physical character of light." If we suppose a dioptric apparatus to be perfect in its capacity of transferring isolated pencils of light, giving separate impressions from each illuminated point in an object, the limit of vision *for that object* will be measured by the visual magnitude of interspace between the illuminated points, provided that interspace does not exceed or fall short of the measure of the percipient element on which each single impression falls. Therefore the finer the percipient element and their interspaces, the finer may be the delineation of detail belonging to an object which detail shall yet be distinctly seen. But microscope objects generally (and some in particular, *e.g.*, closely ruled lines) which cannot be distinguished by the naked eye because their retinal images (16 times smaller) can have no appreciable dimensions, may be rendered visible with the help of such amplification as will spread their detail, *e.g.*, lines and interspaces, so as to fall singly upon the percipient retinal elements. And, so far, magnifying power is *necessary* for vision of minute objects, in order that the images of their structural details may correspond with the dimensions of the percipient elements. But each object so magnified should receive its due illumination in order that the impression of each detail on the retina may fall with sufficient intensity, as well as on the right

place, *e.g.*, microscopic intervals between ruled lines together with the lines themselves must be rendered visible by contrast of light and shade, as well as by equalisation of their scale of size with the dimensions of the retinal percipient elements. Hence the necessary relation between magnifying power and aperture of a microscope objective. But supposing in the next place that there should arise with the fulfilment of these conditions a new difficulty—and the case does so arise—that, namely, of diffraction, are we to interpret it as a failure of the microscope or of the eye? In considering this question the following facts must be kept in mind:—1. There are two distinct sources of diffraction. When points in an *object* become self-luminous by the diffraction *occasioned in the object*, so much detail is added to the picture by a wide angled objective which takes in such diffracted rays and re-produces by its focussing function the image of the diffracting particles. Such diffraction is, therefore, a source of gain for which the microscope is to be credited. 2. The second diffraction effect has been already explained as the necessary consequence of the reduction of the microscope image into a bundle of bright pencils entering through the pupil of the eye, and as has also been explained, the evil results of this condition are attributable to excessive angular amplification, but not to faulty lens-construction. The eye is not constructed to work with such abnormal conditions, and vision is, therefore, impaired physiologically. 3. As a matter of fact the modern microscope lens-combinations work so well that undulations of shorter wave length than those which excite sensations of light define (without shewing "interference") finer lines and interspaces on a photograph surface than have ever been seen by the eye, looking at the same object through the same lens-system and under the same illumination. That is to say the retina is not so sensitive as photograph paper, and the dioptric media of the eye cannot transfer the microscope image so perfectly as it can be thrown directly on the chemically prepared paper through the microscope.

Thus then it is plain that resolution of minute objects is not limited by characters of physical light but by physiological in-

capacity of the eye to perceive distinctly the objective images of minute structural details under conditions of illumination which are not suited to the distinguishing power of the retina. The constitution of the eye is, in short, the master condition which fixes the limit of resolving or defining powers.

Let us now consider the possible performance of the retina as measured by the actual dimensions and position of the percipient elements. The *cones* of the bacillary layer of the retina at its most sensitive spot (the *macula lutea*) have a diameter at their base (where the focal points of the image fall) of about $\frac{1}{8000}$ inch, and the distance between their centres is about $\frac{1}{6300}$ inch. The *rods* which are not found at the yellow spot, but which everywhere else are crowded closely together, have a diameter of about $\frac{1}{12500}$ inch, and the distance between their centres is nearly the same—say $\frac{1}{12000}$ inch.

The dimensions of the retinal image of an object subtending a visual angle of 60 seconds is $\frac{1}{5770}$ inch.

To show the relation of these figures to each other the following extract from Donders will be useful :—

"The first exact appreciation of the physiological question, we find in Hook's essay on Distinct and Indistinct Vision (1738). He investigates the angular distance required to observe two fixed stars separately, and he found that among one hundred persons scarcely one is in a position to distinguish the two stars when the apparent distance is less than 60 seconds. Subsequently similar investigations were carried on by Mayer, and in our own time by Volkmann, Harting, Weber, Bergmann, and Helmholtz, for the most part with parallel lines or gauge net. It is evident that, for two minute points of light to be seen separately, the centres of their images *must lie further apart from one another than the breadth of a percipient element of the retina* (about one and a half times). If the centres fall at both sides precisely on the boundaries of the same element, this element alone will then receive as much light as the two adjoining elements between which it is situate ; while, in order to see two separate points, a less illuminated space must remain

between them. In using stripes and wires, not only the interspaces, but also the thickness of the stripes or wires come under consideration, and in the calculation Helmholtz has, therefore, assumed the angle corresponding to the sum of a line and an interspace—that is, to the distances of the central points of the two adjoining objects. The retinal *elements* must then, at least, *be less* than the retinal *images* corresponding to this angle. Harting and Bergmann have some measurements in which the angle thus calculated is less than 60 seconds. Almost invariably, however, it amounts to from 60 to 90 seconds. By using extremely thin cobweb filaments, the angle in Harting's experiments proved much greater (2 to 3′) than when metallic gauze with thicker filaments was employed. To this cause, no doubt, it is also to be attributed that Volkmann, who made use of cobweb filaments, found particularly high values." (See article in note to page 460).

The dimensions of the *cones* of the retina are, as above quoted, $\frac{1}{8000}$ inch for their thickness, and $\frac{1}{6300}$ inch for their distance from centre to centre as they stand closely crowded together at the "yellow spot" on the axis of vision. But outside of this axial spot the diameter of the cones increases up to about $\frac{1}{4000}$ inch, and towards the equator of the eye are separate from each other by a still wider interspace of $\frac{1}{3200}$ to $\frac{1}{2600}$ inch. This interspace is entirely occupied by the *rod* elements, whose thickness is about $\frac{1}{12500}$ inch, and their distance from centre to centre about $\frac{1}{12000}$ inch. (See figures 1, 2, 3).

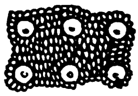
View of the Surface of the Layer of Rods and Cones on which the Retinal Image is formed, magnified about 500 *times.*

Fig. 1.—Cones of the yellow spot.
Fig. 2.—Cones on the outer margin of the yellow spot with intervening rods.
Fig. 3.—Cones and rods in the equatorial region of the eye.

Fig. 1.

Fig. 2.

Fig. 3.



How important such an arrangement is for microscope vision may be gathered from the following calculations, it being admitted that the conversion of luminous waves into nerve movement, which constitutes the first step in the act of seeing, really does take place in these elements:—

Let us suppose an object to contain lines or particles distant from each other by the $\frac{1}{100000}$ part of an inch, and that we desire to know the requisite magnifying power which shall bring the retinal images of these lines up to such dimensions as would enable them to be distinctly formed on the retina so that the lines or particles shall be perceived separately by the *cones*. Now an amplification of $\frac{1000}{1}$ should increase the distance between the lines so that in the microscope image they would be situate $\frac{1}{100}$ of an inch apart, and their retinal image would then shew them $\frac{1}{1800}$ inch apart. This would nearly cover four cones, having a distance of $\frac{1}{6300}$ inch apart, *i.e.*, the amplification of $\frac{1000}{1}$ would be unnecessarily high for a retinal image *thrown on the axial yellow spot*. But an amplification of $\frac{250}{1}$ would, by a like calculation, give a retinal image in which the particles would stand $\frac{1}{6400}$ inch apart, and as this corresponds with the actual distance between the centres of the *finest* cones ($\frac{1}{6300}$), the *amplification necessary* to see lines distant from each other by $\frac{1}{100000}$ inch is only $\frac{250}{1}$ times. This proves conclusively that *the difficulty of resolving lines at* 100000 *to the inch depends upon other circumstances than magnifying power*, and points to the defect of illumination and defining power.

But, further, the retinal image of an object subtending a visual angle of 60 seconds is 0.00438 m.m. (Donders), which, converted into a fraction of an inch, is $\frac{1}{5840}$; and this again corresponds nearly with the limit of distinguishing power of the finest retinal cones, as above given, $\frac{1}{6300}$ inch. That is to say *the retina does not distinctly appreciate any closer interval than that given by an object subtending a visual angle of* 60 *seconds or a few seconds less.*

The question naturally follows—if a higher magnifying power be used does it confuse retinal perception by spreading the retinal image of a line a point over several cones? The answer is *not if*

the retinal image is well defined and its points not blurred by dispersion circles. And the reason of this will appear on further consideration of the anatomical distribution of the cones as they lie further from the axial centre of the yellow spot. Just at this centre nothing but closely packed cones is found, and, therefore, *acuteness of vision is here greatest, reaching its utmost limit of resolving power.*

"The arrangement of the cones at the yellow spot is surprisingly regular. They are disposed in curved lines which converge towards the centre and produce the appearance of shagreen or that produced by the engine-turned back of our watches. This arrangement, which on physiological grounds had been predicted by Hensen, is perfectly regular, the cones successively diminishing in diameter from the periphery of the yellow spot to the margin of the forea."*

Outside the centre the distance between the cones gradually increases. At first each cone is surrounded by a ring of *rod* elements, then by a double and triple row successively, until, as the figures above given show, the distance between their centres increase to $\frac{1}{3200}$, and at the equatorial regions to $\frac{1}{2600}$ inch in place of the $\frac{1}{6300}$ inch at the centre of the yellow spot. From this it follows that a magnifying power of $\frac{500}{1}$ which will form a retinal image of $\frac{1}{3200}$ inch dimensions from an object having an actual dimension of $\frac{1}{100000}$ inch will, *if this image fall upon part of the retina outside the yellow spot*, just fulfil the conditions of separate and distinct appreciation by the retinal cones, and a power of $\frac{800}{1}$ will not separate the lines or particles by a greater distance than that which separates the cones of the equatorial region. This corresponds with actual experience in the use of the microscope. For, according to Helmholtz, Abbe, Harting, Dippel, and others, the highest *serviceable* power for resolving difficult tests does not exceed 500 to 800. And it has been already pointed out that with such high powers diffraction and

* Max Schultze, Sydenham Society's Edition of Stricker's Histology, vol. 3, page 282.

illumination are the real difficulties to be overcome. It is not, therefore, without reason that Helmholtz has so strongly emphasized the part played by the *photometric relations of light* in the use of high powers, and proved how rapidly the brightness of image falls off as amplification is increased; or, that Abbe has insisted upon the importance of perfecting objectives of medium power instead of seeking to obtain enormous amplifications and employing deep eye-pieces.

In regard to the fact that a highly magnified image must, physiologically, involve the employment of portions of the retina outside the direct axis of vision, it is to be observed that the slightest movement of the eye on its axes will suffice to throw the image upon any required part of the retinal surface round the axial centre, and that this act is constantly being performed in the ordinary use of the eye when attention is directed to such lateral images.

It is also worthy of notice that the *rods* which intervene between the *cones* being equally percipient elements must have their special uses. The thickness of these *rods* ($\frac{1}{20000}$ to $\frac{1}{25000}$ inch) is so much less than that of the *cones* that their function can scarcely be supposed to be that of perceiving *form or magnitude*. But, as percipient elements greatly outnumbering the cones, an important appreciation of the varying amount of light and shade by which the delineation of form is sustained, and by which the pictorial effect of the microscope is distinguished, may with great probability be attributed to their action.

In the foregoing observations the physiological conditions of microscope vision have, it is hoped, been made clearer by placing them upon an anatomical basis which, though as yet still far from perfect, indicates at least an actual and natural foundation upon which to build a theory of vision. A very brief reference to the dioptric function of the eye will suffice to shew how greatly microscopic vision is affected by its special excellences and peculiar defects as an optical instrument.

Supposing every outline, surface, prominence, and depression of an object to be accurately represented in the optical image produced

by the microscope, this image must next be transferred through and by means of the eye structures, to the focal plane of the bacillary layer of *rods* and *cones* situate at the back of the retina. In the next place the retinal image must represent the microscope image by exact quantitative differences of white light, supposing the object to be colourless, or if the object contains colour, by an exact counterfeit of the coloured microscope image. By quantitative differences of white light is meant the gradation from white to less white and so on to black (by absorption of white light), and the coloured image must necessarily reproduce as many colours and as many gradations of each colonr as exist in the object. But the healthiest and most normal eye cannot accomplish all this withont loss of light or deduction from accuracy of definition. There are defects in the physical transmission of the image arising from spherical aberration and chromatic dispersion of the eye, as well as from material obstruction to the direct passage of rays of light. The cornea, for instance, has a curvature which differs in the vertical as compared with the horizontal direction, and its substance is far from being perfectly translucent. Then the crystalline lens contains within its substance six diverging planes formed by the abutment against each other of the ends of the cell fibres of which the lens is composed. These planes, whether actual fissures filled with granular cement, or boundary lines formed by simple end to end abutment of the cell membrane of the fibres, cause a break of continuity and homogeneity of substance, and the consequence of this arrangement is that bright points seen at a distance appear with a halo of rays, the images of the radiating structure of the lens. The general substance of the lens is also, like that of the cornea, sufficiently milky to affect the passage of light through it, and all these effects increase with *age*. As respects the retina itself a far more deteriorating effect than is commonly supposed to be possible actually occurs in every healthy normal eye. This is described by Max Schultze in the following terms* :—

* Zeitschrift für wissenschaft: Zoologie, Band 8, p. 91. See Stricker's "Human and Comparative Histology," Sydenham Edition, vol. 3, p. 288.

"We, however, habitually see through another yellow screen, present throughout the whole extent of the retina, namely, the narrow-meshed plexus of its capillary vessels which lies in front of all the percipient elements. The quantity of the rays of the spectrum, which a single layer of corpuscles, sometimes standing on their edges and disposed like rouleaux of coin, absorbs, is very considerable, as an examination with Browning's spectroscope shows. The hœmoglobin lines are visible, and a considerable portion of the rays at the violet end of the spectrum are lost. With thicker layers of blood corpuscles, like those circulating in the larger retinal vessels, the absorption effects would clearly be much more considerable. Alterations in the blood affecting this absorption power for certain luminous rays, must, necessarily, lead to unusual perceptions of colour."*

And, here, another peculiarity of the retinal structure requires notice. Nearly in the axis of vision, and at some distance to the side of the optic nerve entrance, an intensely yellow pigment is deposited between the elements of the different layers of the retina. The centre of the "yellow spot" is depressed on the surface looking towards the front of the eye, to form the forea centralis. This colouring matter, most intense in the fossa, is completely hyaline, and only so far disturbs the transparency of the retina at this part, that it absorbs a considerable portion of the violet and blue rays before these reach the layer of cones. With the aid of Browning's spectroscope Max Schultze has distinctly perceived the shortening at the violet end of the spectrum under the microscope.†

* An important fact must not be omitted, namely, that there *are no retinal blood vessels in front of the yellow spot.* The significance of this fact is two-fold, since there can be no entopic shadows thrown on this most sensitive part of the retina by blood vessels or contained blood, whilst their absence at this spot implies, that the deterioration of vision caused by such shadows really does happen over those parts of the surface, outside the axis of vision, on which images may be thrown.

† The yellow spot is less sensitive to weak light than other parts of the retina. It has been long known that many stars of inferior magnitude are seen more brightly if looked at somewhat obliquely, than when their rays fall full upon the eye. This can be proved to depend partly on the yellow color of the yellow spot, which weakens blue more than other rays. It may also be partly the result of the absence of vessels at this yellow spot, in consequence of which the direct contact with life-giving blood fails.

Lastly, in every eye there exist, either in the vitreous humour, lens, (with its capsule) or cornea, particles which, though not ordinarily seen in looking at objects with the naked eye and with natural daylight, intervene with the effect of shadows throwing opacities whenever a bright light (such as the microscope image with lamplight) is poured through the pupillary aperture.

The defects hitherto noticed appertain to every healthy eye, and are inherent in the histologic constitution of the structures forming the optical apparatus of the eye. That they do not, strikingly, impair the excellence of vision, *as ordinarily exercised by the naked eye*, under suitable conditions of daylight and favourable position of objects seen, is because their ill effects are partly remedied by other circumstances. But it is just when the natural conditions of vision, accommodation of the eye, and muscular movements directed by the mental perception, are most interfered with and strained, — namely, during observation of objects through the microscope—that *every natural defect is exaggerated by the abnormal conditions of vision thus brought about*. The necessity of directing the "mind's eye" to images formed on parts of the retina outside the central axis of vision (*i.e.*, the act of looking sidewards,) has been already pointed out in connection with the anatomical disposition of the *rods* and *cones* of the retina which controls its distinguishing power for coarser details or for more amplified images of finer details. This action is however but part of the whole scheme on which depends the transmission of a microscope image, when physically defined on the retina, to the sensory centres: namely on the susceptibility of the normal and healthy percipient elements to subtle differences of light and shade, (*i.e.*, maxima and minima of intensity of æther undulations,) either as undecomposed white light, or as decomposed into separate colors. In the same object the extreme range from positive to negative, both of white light and of colors, as well as differences of surface from those of least magnitude to those of relatively large areas, may present themselves. Now even under the most favorable conditions of light and shade (daylight illumination,) and of definition (normal

use of the unarmed eye,) contrast of outline, coloring, relative light and shade, (as in looking at a landscape) is recognised mainly by a *mental comparison rapidly effected by quick alternate direction of the axis of vision* towards one boundary or another, from one surface to its next contiguous surface, and so on. And this mode of using the eye, long continued discipline of mental vision alone can teach, until finally the inexactitude of the actual retinal images is so compensated and rectified by experience that the adult eye rarely fails of a correct conclusion. The mental vision thus taught and exercised is so different from the retinal impressions (because every imperfect or unnecessary impression is discarded by the mind,) that people *believe what they see simply because they see what they believe.* Now the same training is needed for vision through the microscope. With the monocular instrument sharpness of impression and of direction predominates, whilst the peculiar advantages of vision with two eyes are lost. With the binocular these advantages are regained, but the picture is a composite one with strong perspective effects, though the capacity of appreciating linear direction to the axis of each eye singly is lost. Each instrument has its special uses, but the eye requires training for both, and in all microscope practice *fatigue of the eye* physiologically affects the distinctness of vision. We know that too much light involves fatigue of the retinal perceptive faculty from over intensity of impression. "*In a single minute the impression produced by a bright surface has lost from a quarter to half of its intensity, and yet the observer does not notice this fact until contrast brings it before him.*" (See Helmholtz's Popular Lectures, page 225.) Too little light, again, involves fatigue from strain of attention, and consequent tremor of the muscles of the eye. For the definition of delicate outline depends upon trustworthy recognition of subtle gradations of light and shade, and suffers in proportion as the brightest parts of a picture fade. If the absence of light produce a *lower* tone than is requisite for definition, the mental direction of the movements of the eye for observation of contrasted light and shade is not called into action, or if forced it fatigues still more. If, again, an object

presents surfaces of relatively large area which are much brighter than the other parts, corresponding portions of the retinal percipient surface become fatigued, and vision is disturbed by *after images*, whilst those parts which have relatively too low a tone fade from sight. The act of seeing thus exercised upon images of very minute objects in the midst of large bright fields is greatly burdened in the attempt to discern fine structure. On the other hand the more an object is needlessly magnified the less clearly will its outlines be defined because the delineating pencils of light are scattered and the intermediate details lose needful light and shade. Whether therefore the brightness of image be too much with low amplification, or too little with high amplification, the eye will not perceive what the microscope with proper management can nevertheless perfectly delineate.

Although we have barely glanced at a few of the principal defects inherent in the anatomical constitution of the eye, the limits of this paper have been so far exceeded that it is impossible to enter upon any discussion of the imperfections of the dioptric media of the eye considered as an optical apparatus. It has long been known that spherical and chromatic aberrations do exist in the most healthy organ; and it has been the province of the physiologist to account for the general perfection of vision, in spite of the very numerous structural and functional defects of the eye. It has, for instance, been shown how accommodation for focal distance is provided for by muscular movement operating upon the position of the lens, and how imperfect form and colour are counteracted, and contrast of light and darkness, appreciated by the simple act of changing the axial direction of the eye. But it is necessary to go much further than this in any attempt to set up a theory of vision. In the first place, the sensation of sight has to be explained, or at least the furthest boundary of physical impression has to be traced, and the means discovered by which the excitation of the separate nerve-fibrils is produced. And there seems little reason to doubt that anatomical investigation and physical science will eventually accomplish these ends. A theory of vision, so far as it relates to the complete and

accurate apprehension of the form and colour of external objects, may then be possible. Meanwhile the facts which have been ascertained from the study of the dioptrics of the eye, cannot be disregarded in our estimate of microscope vision. For the capacity of the eye as an optical instrument has a direct relation to the performance of the microscope ; whilst as a percipient or sensory organ it dominates over the whole subject of light and its properties. The limit of vision, whether by the unassisted eye or when assisted by optical apparatus, remains fixed by the distinguishing power of the retina. And under ordinary conditions of illumination, the images formed by the eye in its normally healthy state are equal in delicacy and accuracy to the limits which the dimensions of the retinal cones and rods set to the delicacy and accuracy of sensation. To these limits the microscope sets, properly speaking, no opposition. The function of this instrument is to bring minute objects within the powers of recognition which the eye possesses. And as a magnifying instrument it can do more than this; but the failure lies in the conditions of illumination on the one hand, and in the limits of visual perception on the other.

Notes on Carboniferous Encrinites from Clifton and Lancashire.

BY J. G. GRENFELL, B.A., F.G.S.

Read before the Geological Section of the British Association, Bristol, 1875.

I HAVE been fortunate in obtaining some fine specimens of Encrinites from the base of the Carboniferous Limestone in the gorge of the Avon. They occur in the two lowest beds of the Black Rock Quarry, just above the Lower Limestone Shales. Four genera are found in the two beds—*Poteriocrinus, Cyathocrinus, Actinocrinus, Rhodocrinus*—which latter genus does not include Phillips' *Gilbertsocrinus.* By far the commonest species is *Poteriocrinus plicatus* (Austin), of which I have obtained a fine series. Hitherto only the body had been found—the arms, proboscis, and stem being unknown. I will now describe this species, and in so doing, and throughout the paper, I have adopted De Koninck's nomenclature for the plates which form the body and arms. (*See plate VI. figs* 1 *to* 4, *and plate VII., figs.* 1 *and* 2.)

I can find no traces of the three concealed plates above the column mentioned by Phillips and Major Austin, and whose existence was doubted by De Koninck.

The *basals* are five, as described by De Koninck and Major Austin. They articulate to the column by radiating ridges and furrows. Sometimes at the points they are lowered, so as partially or entirely to overlap the top point of the column.

The five *subradials* are well described by De Koninck and Major Austin. All their edges articulate by ridges and furrows at right angles to the surface of the plate.

The *radials* are seven in number; of these the first only was known to the above-mentioned authors. These first radials articulate to the subradials by ridges and furrows, but this is not the case with their lateral articulations to one another. They are followed by six radial plates, and a cuneiform one, where the first bifurcation takes place. Then follow twelve *brachial* plates and a cuneiform one to the second bifurcation; then an uncertain number, not less than twelve, to the third bifurcation; and then eighteen and a cuneiform to the fourth bifurcation. The number of rays is thus eighty.

All the plates of the arms are more or less laterally wedge-shaped, with the thick end of one fitting the thin end of the next. Up to the second bifurcation they all articulate by radiating ridges and furrows, and the rest probably do the same. This articulation of the arm-joints has not commonly been observed.

The *anal* plates are five in number, while De Koninck gives for the genus 4 or 6, and they do not agree with his generic figure. They are arranged in two vertical rows; the two lowest are pentagonal, the two next are hexagonal; the last is probably hexagonal. (*See plate VI., fig.* 2.)

The proboscis is by far the most interesting part of this species, being composed certainly of upwards of 1000, and probably of upwards of 1300 separate plates, and exhibiting a structure hitherto undescribed amongst the Crinoids. Professor De Koninck, speaking of the probosces of the Crinoids, says that some are formed of many hexagonal plates, as *Poteriocrinus gracilis*, (M'Coy), others are membranous and formed of a single piece. As he does not describe any membranous ones in his work. I fancy he may have got this notion from Austin's figure of *P. crassus*, or perhaps from a Clevedon

specimen in the British Museum in bad preservation, which looks very much like a wrinkled membranous tube.

These specimens exhibit the following structure. One of them is 4½ inches long by ¾ inch wide. Above the anal plates are two plates side by side, about twice as wide as long, which have two prominent lateral ridges on each side; these are followed by two shorter plates which have two lateral ridges. These four plates give strength to the base of the proboscis, and are followed by the ordinary plates. The proboscis is formed of long narrow plates, arranged in five horizontal rows, and set at right angles to the axis of the proboscis. The most prominent of these are pairs of plates bearing high ridges, which are pressed against each other so as to form a single strong ridge across the proboscis. Of these there are in one case 43. Each of these pairs is separated by three, and in one case by five plates, of which the central one is the largest, and all of which are rather higher in the centre, so as to form five longitudinal ridges (*Plate VI., figs.* 1 *and* 3.) These smaller plates articulate by crenulated edges.

The interior of the proboscis shows the underside of the three intermediate plates, but instead of the two ridged plates shows only one broader one of which the ends are bifurcated. They thus appear to underlie and hold together the ends of the ridged plates.

I have found some broad plates free, which appear to have a deep socket at each end, and which seem to be different from the plates visible on the exterior. It is possible that the bifurcation mentioned may be only a section of these sockets, but further investigation will be required to settle this point. (*See plate VII., fig.* 2.) Among the detached plates I have found some short ones which are bent at a high angle, and which do not seem to have been subjected to compression. (*See plate VII., fig.* 2.) It is difficult to assign to these their proper place, unless the proboscis was not circular but oval in section, on one side at least. The position of the proboscis was not central but on the side of the anal plates; this is evident in nearly all tho specimens exhibited. In the interior of the head of one specimen are a number of very small

[redacted]

plates, which, perhaps, were situated on the base of the proboscis on the opposite side to where it joins the anal plates.

The stem is smooth; the joints shorter near the summit, and articulating by radiating ridges and furrows. In one specimen the first side arm appears at a distance of eight inches from the head, is very small and nearly an inch from the next. At eleven inches they become very numerous and larger. Another specimen showing only the base of the stem has fifteen to twenty side arms in the space of two inches, and it shows that the stem diminishes in diameter towards the base. The plates from which the side arms spring are rather thicker than the rest. One of these side arms, detached, is four inches long. The plates composing the side arms do not exactly fit one another as pointed out by De Koninck. The average length of the stems seems to be about thirteen or fourteen inches. Length from top of column to top of proboscis 4·8 inch. The rays were probably about the same length as the proboscis.

Poteriocrinus rugosus (Grenfell). (*See plate VII., figs.* 3, 4, 5.)

I propose the above name for a new species of Poteriocrinus in the Museum at Clifton College. It was found in the Lower Limestone Shales in the Avon gorge, and formed part of the Bernard collection.

The body is conical, the base slightly concave, pentapetalous, the edges crenulated. The lower edge of the basals partially overlaps the base as shewn in Pl. vii. fig. 5. An obscurely pentagonal, nearly circular line marks the margin of the part of the column in which, as in the recent Pentacrinus, the calcareous matter was more loosely arranged, and which contained the longitudinal fibres. This portion might conveniently be called the fibriferous area: it is well-marked in Rhodocrinus.

The *basals* are five, wider than long, and shaped somewhat like *P. plicatus*. The alimentary canal is small and pentapetalous.

The *sub-radials* are five—three pentagonal, the other two hexagonal. All have their lateral articulations depressed, so as to give a characteristic rounded shape to the plates.

The *radials* are three, wider than long; they are rounded in the same way as the sub-radials. The first articulates to the second by

its whole breadth; from the third or axillary radial spring two rays which, in one case, are both simple up to the seventh plate where they are broken off; in two other cases, one ray remains simple up to the twelfth plate where it is broken off, while the other bifurcates a second time after the third plate, and the two simple rays are side by side with the divided rays outside. It is noticeable that these extra rays do not occur on opposite sides of the anal plates as if to protect that portion, as suggested by Major Austin in the case of *P. pentagonus*.

The first radial articulates to the second by two ridges. The other two arms are wanting. The channel along the arms is very wide and deep.

The *anal* plates are five, arranged in two vertical rows as in *P. plicatus;* the lowest is pentagonal, the rest hexagonal; all their angles are depressed. (*See plate VII., fig.* 4.) The articulations of the arm joints have an irregularly waved edge.

The surface of the body plates is rough; that of all the plates of the arms is strongly wrinkled, especially at the sides.

The third radial is remarkably wide in proportion to the calyx.

This species resembles *P. pentagonus* and *longidactylus* (Austin) in shape and general arrangement of parts; it is well distinguished from them by the depression of the angles and lateral articulations, and by the roughness of the surface. The height of the calyx is ·3 inch; diameter, ·4 inch; total length of the specimen as figured, 1.3 inch; width of third radial nearly ·3 inch.

Rhodocrinus verus (Miller). (*See plate VII., figs.* 6, 7.)

I exhibit a fine specimen of this species from the lowest beds of the mountain limestone already mentioned. The arrangement and ornaments of the plates leave no doubt that this is the species on which Miller founded the genus. The arms, however, were unknown to him, and the column had not been found attached to the head.

The arms are ten in number. They bifurcate only once, so that the number of rays is twenty.

The *brachials* are six in number and adhere to the calyx; above

the sixth axillary one are two plates adhering laterally to each other; above this the arms are free and composed of a double series of joints which are closely tentaculated.

The *stem* is cylindrical, and composed of alternately thicker and thinner joints, but the difference is not great.

It appears to have been of great length in proportion to its thickness, as a detached stem, apparently of this species, is over a foot long and shows no signs of head or side arms.

The alimentary canal is small and apparently circular, the fibriferous area is pentapetalous. Height of calyx ·7 inch; from base to top of arms two inches; width of calyx ·9 inch.

This species is evidently very local, as the British Museum has only one very bad specimen; Jermyn Street Museum none; and Major Austin two from this neighbourhood, also in poor condition.

Miller's specimens have unfortunately disappeared from the Bristol Museum.

It is a question whether this species should be called *verus*. Miller's figure (Crinoidea, *plate I.*, *fig.* 1) is from a drawing sent him by Mr. Stokes, of Dudley, and is a Silurian fossil, quite distinct from the Carboniferous one, and probably belongs to another genus. If they belong to the same genus, one of the two must evidently be re-named. Professor Phillips applied the name *verus* to the Silurian species, and did not believe that this species was found in the Carboniferous Limestone at all.

Professor De Koninck also writes to me that the name *verus* must be retained for the Silurian species, as it appears in all lists of Silurian fossils.

On the other hand it is quite certain that Miller founded his genus on the Carboniferous species, as his detailed drawing of the plates agrees exactly with the one exhibited. In Morris' catalogue it is quoted as Carboniferous, but with a note on Phillips' view.

If the Silurian species really belongs to another genus they may both retain the name. Major Austin believes that none of the Silurian genera of Encrinites survived in Carboniferous times. I have not seen the Silurian specimen, and, therefore, cannot speak

positively, but in any case it seems to me that the name *Rhodocrinus verus* should be retained for the Carboniferous species, as that is clearly what Miller intended. If, however, geologists generally adopt De Koninck's view, I should propose that this be called R. radiatus.

Rhodocrinus verisimilis (Grenfell). (*See plate VII., figs.* 8, 9, 10.)

I have given the above name to a new species of Rhodocrinus found with the last, which in many ways it closely resembles. The general arrangement and shape of the plates of the body agree with Miller's detailed figure of the genus. The *sub-radials* are hexagonal and wider than long.

The *radials* are three, the first heptagonal; second, hexagonal; third, normally heptagonal. They bear prominent longtitudinal ridges like *R. verus* and *stellaris*, but in the present species these are wider and flatter; that on the second is wider in the middle, and the prominences are continuous, not interrupted as in *R. stellaris*.

The arms are ten. The *brachial* plates five to the first bifurcation; the two lowest are hexagonal, and adhere to the calyx; they are short, wide, and flat; are followed by three plates to the second bifurcation, which are also short, wide, and flat; after this the rays, as in *R. verus*, are composed of two series of joints, and are tentaculated, still remaining comparatively broad for their length. Total number of rays, forty.

The shape and arrangement of the brachials closely resemble those of *R. verus* (*see plate VII., fig.* 10), and are important, as I hope to show that they serve to separate these species generically from Phillips' genus Gilbertsocrinus. The *inter-radials* have triangular depressions at their angles, so as to form star-shaped ornaments as in *R. verus*, but the centre of the star is here much wider. The *stem* is cylindrical; the joints alternately thicker and thinner; the alimentary canal small and circular; the surrounding fibriferous area is pentapetalous. Height of calyx, ·38 inch; diameter, nearly ·6 inch; length from the base to top of arms, 1·1 nch. One of the specimens in my collection, which is in bad

condition, seems to be this species; it has the dome considerably elevated.

Verisimilis is distinguished from *verus* by its smaller size, by the rays being wider, shorter, flatter, and double the number, by the shape of the second brachial, and to a lesser extent by the ornaments of the radials and inter-radials; from *stellaris* (De Koninck), and *granulatus* (Austin), by the star-shaped ornaments on the inter-radials which are absent in those species. The four specimens in my collection are the only ones I have seen, unless a very bad specimen from Clevedon in the British Museum belongs to this species.

I now pass on to the Lancashire species, on which Phillips founded his genus *Gilbertsocrinus*, and I hope to show that, although his generic description is inaccurate, yet the genus is a good one and must be retained. His description is as follows:—"Base hollow; basals five, forming a pentagon; suprabasals (the subradials of De Koninck) five, hexagonal, forming a decagon with five re-entering angles, from which spring five heptagonal first costals, five hexagonal second costals bearing a pentagonal scapula, supporting joints which combine into round arms perforated in the centre. (These costals and scapulæ are the radials of De Koninck). The first intercostal is pentagonal.

De Koninck and Le Hon have shewn that the whole of this description, as far as regards the number and arrangement of plates, applies equally well to Rhodocrinus, and, therefore, they do away with the genus Gilbertsocrinus, but they take no account of the very peculiar structure of the brachials above the scapulæ, which Phillips does not describe in words, but of which he gives a detailed drawing in the case of *G. bursa*. Rofe, and I believe Billings also, have given up Gilbertsocrinus.

The inaccuracies in Phillips' description are his making the scapula or third radial, and the first intercostal or inter-radial pentagonal. I have examined the specimens of *G. bursa* in the British Museum, and find that in every case the third radial is normally heptagonal, though a plate is often wanting on one side or

the other, and I have a specimen in which this plate is in one case pentagonal. *G. calcaratus*, also in the British Museum, has the third radial normally heptagonal.

The British Museum specimens of *bursa* have the first inter-radial generally pentagonal, but I have three specimens, which I believe to be this species, in which this plate is generally hexagonal. There are a considerable number of specimens labelled *G. mammillaris* in the British Museum, and in all of them this plate is hexagonal. It is quite clear then that these two points must be removed from the generic description.

Professor McCoy unfortunately gave the name *abnormis* to an Irish specimen, which has the third radial heptagonal and first intercostal hexagonal, on the ground that in all others of the genus these plates were pentagonal. His specific characters thus fall to the ground, and the only points in which his description and figure differ from *bursa* are, the larger size, the absence of marked depressions at the angles of the plates, and the statement that the proboscis is central.

The depressions at the angles are not well marked in all specimens of *bursa*, and therefore I do not attach much importance to this. With regard to the proboscis, I would remark that no other species of *Gilbertsocrinus* has a proboscis at all, and that the figure does not prove the existence of one in this case. What McCoy calls the proboscis looks just like a raised mouth at the top of a rather conical dome. In this it much resembles a specimen of Mr. Rofe's in the British Museum, which has a row of nearly vertical plates round the mouth, but which cannot fairly be said to have a proboscis. It is true that *bursa* has the mouth eccentric, but I cannot help thinking that some further proofs are necessary to shew that this is not merely a large specimen of *bursa*.

Mr. Rofe writes to me that no reliance can be placed on the number of sides of the plates, especially in the genus Rhodocrinus or Gilbertsocrinus, as they frequently vary on the same specimen. I cannot quite agree with this, as regards the radials, because the specimens shew that *bursa* has the third normally heptagonal, and

mammillaris normally pentagonal. Careful observation will always show which is the rule.

The grounds on which I believe that Phillips' genus Gilbertsocrinus must be retained are, that all the specimens of *bursa*, *mammillaris*, *calcaratus* and two or three new species which I have examined, agree in the very peculiar structure of the brachials and the arm-bases The first brachial is hexagonal; the second also hexagonal, but channelled at top and leading into an orifice which opens into the perforation through the arms: the arm-bases are set on at right angles to the surface of the body, and form a kind of roof over the above mentioned orifices, *(Plate VII., figs.* 11, 12.*)* The orifices are well seen in Phillips' detailed drawing of *bursa*. The axillary plates also between the brachials are developed to a much greater extent than in any other genus, and the irregularity of the plates above the second brachial, surrounding the orifices and the arm bases, is also characteristic. *(Plate VII., fig.* 12.*)*

The difference between this complicated arrangement and the straight-forward arrangement of the brachials in the true Rhodocrini, *e.g.*, *verus*, *verisimilis*, and *granulatus*, is quite sufficient to establish a generic difference between these forms, especially as these orifices are not found, so far as I am aware, in any other genus. The channel at top of the second brachial is fitted in one of Mr. Rofe's specimens with a small semicircular plate which he calls a fillet—it is figured in the Geol. Mag. vol. 2. Mr. Rofe there suggests that these orifices are ovarian, but it seems to me more probable that they are for the purpose of admitting water into the interior. Recent researches on the living crinoids have established the fact, that the ciliæ of the arms set up a current of water which travels down the groove in the arms, passes also in grooves over the surface of the dome, then enters the cavity of the body, and passes through a membrane which filters off the minute organisms which constitute the food of the crinoid, and, finally, passes out through the proboscis. This latter is, thus, simply an efferent tube which serves to carry to a distance from the arms, the water which has already passed through the body.

In the fossil crinoids Mr. Rofe has shown that the only difference is, that the current enters the body at the base of the arms and passes to the central cavity through covered channels under the dome, instead of in open grooves on the top of it.

As the genus Gilbertsocrinus has no proboscis, there is a danger of the water which has passed through the body being immediately returned to it by the arms. This difficulty is met by the peculiar structure I have described. In the first place, the groove in the arms is not continued to the base, but becomes a central passage. This passage is, further, very small, so that only a limited quantity of water passes in that way. The arms, again, are set on at right angles to the body so as to be as far as possible out of the way of the issuing water. In some cases the arms contract in size very remarkably immediately above the base. To meet the deficiency in the supply of water through the arms these openings are made below, and the current from the arms passing over the top of these openings, draws in, mechanically, a supply of fresh water from below, which is further protected from mixing with the issuing water by the over-hanging roof of the arm-bases. This explanation seems preferable to the other because it is unlikely that this genus only should be provided with ovarian apertures, while the absence of a proboscis gives a definite reason why this genus should find it advantageous to have these subsidiary openings. That the perforations in the arms are really ambulacral, and are not for the passage of muscles as has been suggested, seems to me clear from the fact that if they were filled with muscle there would be no means by which the current set up by the tentacles could reach the interior, as there is no external groove.

The genus Gilbertsocrinus may now be thus defined—basals 5; sub-radials 5; radials 3; brachials several, generally irregular; the second brachial channelled at top, and leading into an orifice which communicates with the perforation in the arms; axillary plates well developed; arms round, and generally set at right angles to the body; plates of body generally tuberculate. It will include the following species—*bursa* (Phillips), *abnormis* (McCoy), *calcaratus*

(Phillips), *mammillaris* (Phillips), *Koninckii* (Grenfell), two or three new species which I hope soon to work out, and probably *simplex* (Portlock) which I have not yet seen.

Rhodocrinus on the other hand will contain *verus* (Miller); *verisimilis* (Grenfell); *stellaris* (De Koninck and Le Hon) *uniarticulatus* (De Koninck and Le Hon) *granulatus* (Austin), and probably *globosus* (Phillips) and *costatus* (Austin).

I will conclude by describing a new species of Gilbertsocrinus which I have named *Koninckii* after the distinguished Professor, to whom all students of the Carboniferous Crinoids are so much indebted,

G. Koninckii. (*See Plate VII, figs.* 11, 12, 13.) Shape somewhat conical, with prominent arm-bases, base deeply concave, basals not seen, sub-radials considerably longer than wide.

Radials—first heptagonal, large, and bearing a large pointed tubercle; second hexagonal, the two upper side faces small, so as to make the plate nearly square; third, pentagonal; one of the rows of radials presents the very unusual irregularity of having four radials instead of three—of these the first is heptagonal, the second and third pentagonal, each having lost one of the side faces, though on opposite sides; fourth, pentagonal. I presume this is an accidental irregularity in this specimen.

Brachials—first, pentagonal; second, hexagonal, chanelled and with the usual orifice; above are three or four elongated plates surrounding the circular base of the arms—these latter are set at right-angles to the body, project considerably, and have a central perforation which is larger than in most of the genus. Axillary plates, three; the lowest hexagonal; of the others, one is hexagonal and one pentagonal. Inter-radials twelve. The dome is considerably wider than the calyx, slightly elevated; the plates are as large as those of the body. The mouth, eccentric.

All the plates of the body and dome, with the exception of those round the base of the arms, the second brachials and the sub-radials have pointed tubercles. The five prominent tubercles round the base distinguish this species from all but *G. simplex* (Portlock).

From that species it differs entirely in shape, in its smaller size, in the narrowness of the sub-radials, and in the presence of the tubercles on the body plates.

Height, nearly ·7 inch.
Diameter across arms 1 inch.
Diameter across base ·5 inch.

This specimen comes from Clitheroe.

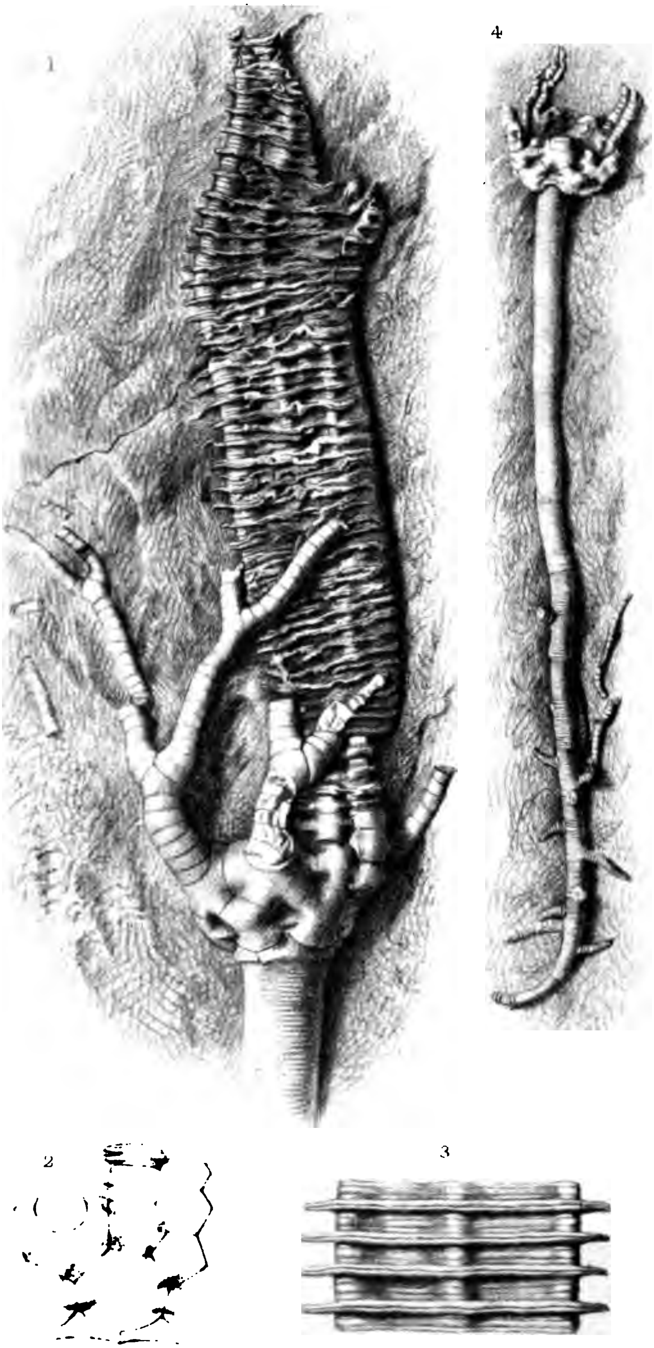
EXPLANATION OF PLATES.

PLATE VI.

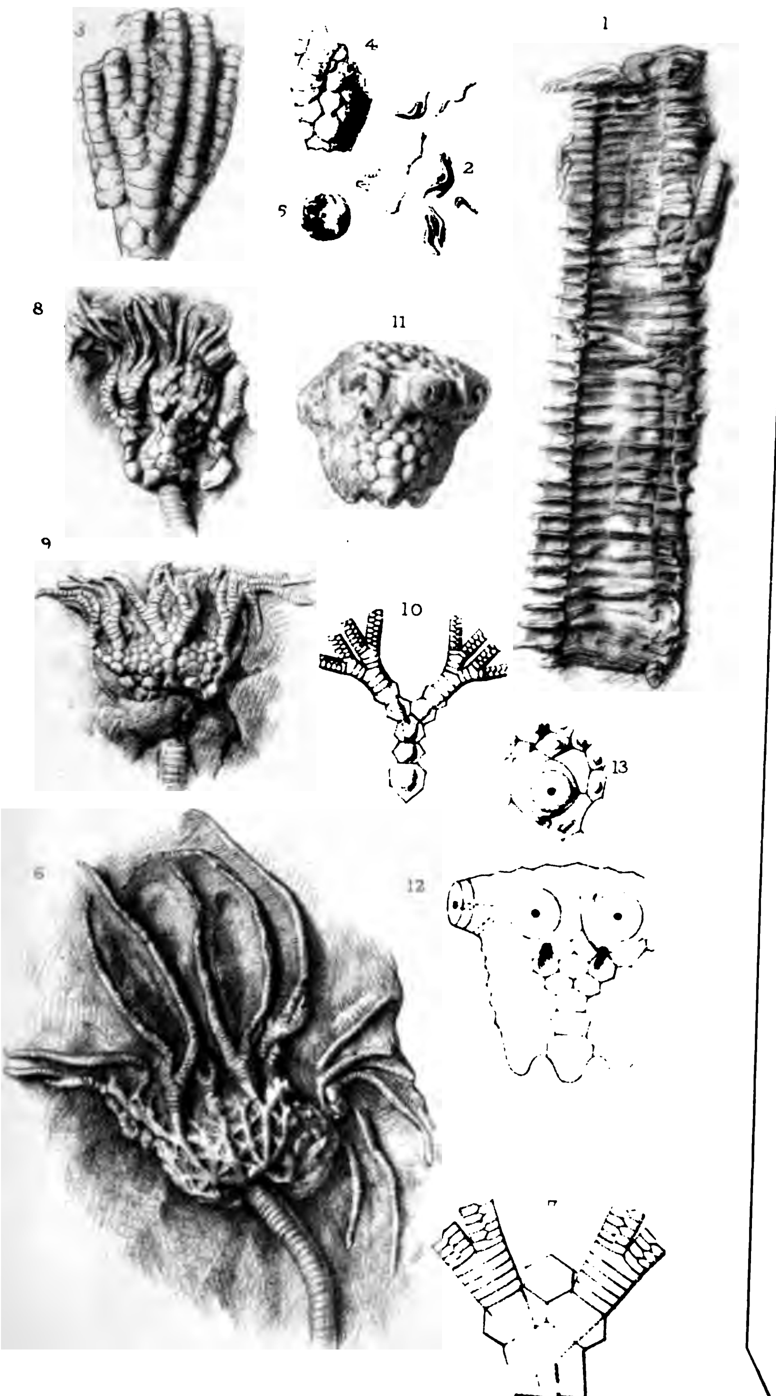
1. Poteriocrinus plicatus, (Austin), natural size.
2. Anal plates of ditto.
3. Portion of proboscis of ditto, enlarged.
4. Another specimen, shewing stem and side arms. Reduced in size.

PLATE VII.

1. Poteriocrinus plicatus. Proboscis from a slab, with three heads and seven stems.
2. Detached plates of proboscis of ditto, on the same slab as Plate VI., fig. 1.
3. Poteriocrinus rugosus. n. sp.
4. Side view of the same, shewing anal plates.
5. Base of ditto.
6. Rhodocrinus verus. (Miller.)
7. Plates of ditto, enlarged.
8. Rhodocrinus verisimilis. n. sp.
9. Ditto.
10. Arrangement of plates of ditto.
11. Gilbertsocrinus Koninckii. n. sp.
12. Arrangement of plates of ditto.
13. Plates round the arm-bases of ditto.



C. Lavars, del J Lavars, lith. Bristol



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J. Lavars, lith. Bristol.

Rain-fall at Clifton in 1875.

BY GEORGE F. BURDER, M.D., F.M.S.

TABLE OF RAIN-FALL.

—	1875.	Average of 23 Years.	Departure from Average.	Greatest fall in 24 hrs.		Number of days in which 0·1 in. or more fell.
				Depth.	Date.	
	Inches.	Inches.	Inches.	Inches.		
January	5·144	3·449	+ 1·695	0·720	1st.	25
February ...	2·248	1·989	+ 0·259	0·789	6th.	11
March.........	1·455	2·160	— 0·705	0·651	7th.	7
April	2·091	1·973	+ 0·118	0·728	7th.	9
May............	2·867	2·376	+ 0·491	0·757	6th.	15
June	3·525	2·561	+ 0·964	0·687	13th.	16
July............	5·991	2·818	+ 3·173	2.900	14th.	15
August	1·785	3·270	— 1·485	0·541	8th.	12
September ...	4·599	3·354	+ 1·245	0·937	21st.	16
October	6·977	3·681	+ 3·296	0·877	9th.	20
November ...	6·085	2·531	+ 3·554	1.295	13th.	17
December ...	1·280	2·548	— 1·268	0.278	31st.	12
Year.	44·047	32·710	+ 11·337	2·900	Jly.14th.	175

REMARKS.—In the foregoing table are shown the quantities of rain measured in each month of 1875, and in the whole year, the averages derived from 23 years' observations, and the departure in each case from the average. To these particulars are added the heaviest falls for the several months, and the number days in each

month on which rain fell to the amount of a hundredth of an inch or upwards.

It will be observed that the total rain-fall of the year exceeded 44 inches. So wet a year has not occurred before within the period of observation, the nearest approach to it having been in 1872, when the quantity was 42·366 inches. The excess in 1875 appears still more remarkable when we take into account the latter part of the preceding year. Strictly the rainy period extended from August 1874, to November 1875. Out of these sixteen months there were but three in which the fall was not above the average, and the total excess in the sixteen months was nearly 18¾ inches.

The heaviest monthly fall in 1875 was in October, which is the most rainy month on a long average. The amount collected in that month was close upon seven inches. January, July and November were also exceedingly wet, the departure from the average being greater in the last named month than in any other.

The two heaviest diurnal falls occurred on the 14th of July and on the 13th of November. On the former occasion no less than 2·9 inches fell within 24 hours, a quantity exceeding any previously recorded here as having fallen in the same interval of time.

The year was not remarkable for snow. At its opening three inches lay upon the ground, and at no subsequent period was the depth so great as this.

Reports of Meetings.

GENERAL.

JANUARY 7th, 1875.—At the first evening Meeting of year, Dr. Burder read "An Account of the Rainfall in Bristol during 1874;" this was printed by order of the Council in last part (Vol. I, Part 2.) Mr. Leipner then made a communication on the "Land and Freshwater Mollusca of the Bristol District," exhibiting a collection of all the species; the list was printed in Vol. I., part 2.

February 4th, 1875.—Dr. H. Fripp, Vice-President, gave a lecture, entitled "A chapter on the choice of a Microscope," illustrated with a large collection of instruments, both English and foreign,—the advantages of each being gone into in some detail. Reference was made to Dr. Abbe's writings, a translation of part of which was printed in Vol. I., Part 2, and a second instalment in the present Part.

March 4th, 1875.—Mr. W. W. Stoddart, F.G.S., F.C.S., gave a verbal exposition of the continuation of his paper on the Geology of the District, viz., Part III., Carboniferous. The text appears above. In the discussion which ensued, Mr. Grenfell doubted whether *Terebratula hastata* was found so low down as the author had put it. From the Gully quarry he had obtained a fine example of corals *Michelinea* and *Syringopora*, and a unique *Aviculo-pecten*. The iron-ore deposits he considered were of Triassic age; and as a source of the iron, suggested that it may have been derived from

the Coal Measures by solution. Mr. Wollaston remarked that in the Millstone Grit series he had found laminæ of ⅛-inch thickness showing Oolitic structure; and he doubted whether in such cases it would be formed by strong currents: he considered such laminæ must have been deposited in still waters. Mr. E. Tawney said he followed the author in holding that the lowest shales belonged truly to the Carboniferous and not to the U. Devonian, as Mr. Etheridge has suggested (*Q. J. G. S.*, XXIII., p. 692), for he has never been able to find any fossil identical with those of N. Devon.

April 1st, 1875.—Mr. E. Tawney read a paper on "Professor Renevier's Geological Nomenclature," exhibiting that writer's large stratigraphical diagram of formations.

May 6th, 1875.—Annual Meeting. The President and other Officers were re-elected, except the Treasurer, who resigned from pressure of affairs. Mr. W. Derham, of Henleaze Park, was elected Treasurer. Three new Members of Council were elected, viz., Messrs. W. W. Stoddart, S. Derham, and A. E. Hudd, in lieu of those retiring by rotation. The Report of the Council was read and adopted. The meeting then passed to the consideration of a new code of Rules; the meeting was adjourned, and at this their adoption was completed.

General Excursion, July 7th, 1875, to Wells and Glastonbury.—A party of seventeen left Bristol by the 8.0 train for Wells. They visited the Cathedral and Palace grounds. Some of the party went to call on the Mayor with regard to the forthcoming excursion of Members of the British Association to Wells during the Bristol Meeting. The party then left for Glastonbury, ascending the Tor. The geologists were not very successful in finding good exposures of the U. Lias beds.

October 7th, 1875.—Mr. E. Wheeler made an interesting communication "On the Birds of the Bristol District," exhibiting part of his private collection, containing the more interesting species and a good series of nests. The text of the paper appears above. Mr. Charbonnier then exhibited a series of silk-producing Moths, including the following species: *Bombyx Yama-mai*, *Pernii*, *Cynthia*,

(Ailanthus-worm), *Cecropia*, *Polyphemus*, *Promethea*, *Luna*. The Tusseh-worm was not in the collection.

November 4th, 1875.—The Rev. W. Hargrave made a communication "On Local edible Fungi," exhibiting many specimens, and explaining whereabouts and when they were to be found, and how they should be cooked. During the discussion, Mr. Leipner said that on the continent there was a notion that to tell whether a fungus was poisonous an onion should be cooked with it, and if the onion did not turn black then the fungus was wholesome; he did not believe, however, in any general rule of this sort,—the only safe way was to identify the species. Mr. Stoddart mentioned cases of illness from eating the stalks of the common Mushroom. Mr. E. Tawney read a paper "On the Limestone of Cannington Park." Mr. Stoddart then exhibited two cases of a double orange, one within the other: the outer one, which seemed of the ordinary shape, when cut open exhibited a smaller one within, perfectly complete, placed excentrically.

December 2nd, 1875.—Before the commencement of the business of the evening, the chairman, Dr. Fripp, Vice-President, proposed the following Resolution, which was carried unanimously: "Resolved, that the sincere sympathy of the Members of the Bristol Naturalists' Society be offered to the relations of the late Mr. William Sanders, F.R.S., F.G.S., whose character and scientific attainments, and whose important services as President of this Society, the Members desire to acknowledge and record with marks of their highest admiration. Entertaining the fullest sense of the loss which the Society has sustained through the decease of its lamented President, this expression of sympathy and cordial tribute of respect and esteem for the public and private worth of their late Associate is directed to be communicated to the family of the deceased."

Mr. W. W. Stoddart, F.G.S., then continued his account of the local Geology, lecturing on the Coal Measures, being Part IV. of the series. This appears above.

BOTANICAL SECTION.

FEBRUARY 18th.—The Annual Meeting of this Section. The Treasurer's Account was audited and passed. Mr. Charbonnier moved, "That the President and Secretary be re-elected, with a vote of thanks for their past year's services;" which resolution was carried unanimously. A Sub-Committee of six Members was then chosen for preparing a collection of plants for the Local Museum in connection with the visit of the British Association to this city.

March 27th.—The first botanical walk this season was taken to Combe Dingle, the members meeting on Durdham Down. *Narcissus Pseudo-narcissus* was gathered below Adams' farm; *Lemna trisulca* in the rivulet; *Viola hirta* on Combe Down; and *Myosotis collina* by the old quarry. In the evening the Local Museum Committee, at the invitation of the President, met at his residence, 47, Hampton Park, and examined the plants collected during the day; and after having refreshed themselves with a most liberal supper, Mr. Leipner took the chair, and the marking off the local plants, as per London catalogue, was completed at 11 p.m.

May 1st.—Taking the train at Clifton Bridge for Portbury, we walked from thence to Portishead by way of the Marsh. At Portbury Station the bank was covered with *Petasites vulgaris;* while the *Chrysosplenium oppositifolium* grew in clusters on the margin of the rivulet. The Water Ranunculus covered the rhines with a white sheet of flower; and *Armeria maritima* was bursting its sheath on the sea shore. Arriving at Portishead we accepted an invitation to spend the evening at Avon Villa, the residence of Captain Dayas.

May 29th.—Meeting at Clifton Down Station, we took an early train to Stapleton Road; here we alighted, and taking the road we came to Stapleton Bridge, and turning to the right, we struck into the fields, and entering Fromè Glen, we found excellent ground for botanizing, with its river, woods, quarries, marsh, and meadows. *Vicia* and *Geranium* of many species were gathered; also *Caltha palustris* in seed, *Cardamine impatiens*, *Sarothamnus impatiens*, &c. At 5.30 we heard voices using botanical names, and hailed with much pleasure Mr. Leipner and the medical students who had come by a later train. After a further search we filled our vasculums, and staying a short time in Stapleton for refreshments, we returned home a more numerous party than at starting.

September 4th.—Proceeding by train to Portishead, we passed through the village, ascending the hill by Simmery Lane, we gained the top road, and having permission to ascend the tower at the farm, we much enjoyed the magnificent view. Continuing our walk, we descended the hill at the Nore, and skirting the shore we finished a very pleasant ramble by partaking of tea at the Hotel. Amongst other plants collected were *Tanacetum vulgare*, *Leptospermum officinale*, *Orobanche minor*, *Chichorium Intybus*, and *Crithmum maritimum*.

October 21st.—The first autumn Meeting was held at the Museum and Library, the President being Chairman. The minutes of the Local Museum Committee and of the Summer Excursions were read and signed. Mr. G. N. Harris was enrolled a Member. The President described certain edible Fungi that were very plentiful in the neighbourhood at this time of the year.

November 18th.—The President after signing the minutes of the last Meeting, drew our attention to the serious loss we had sustained since we last met, in the death of one of our original members, William Sanders, Esq., Fellow of the Royal Society of London, and President of the Bristol Naturalists' Society, who had that morning been committed to his last resting place,—several of the Members present having, as a last token of respect, followed his remains to the tomb.

Dr. Burder was enrolled a Member.

Mr. Leipner gave the subject for the evening, "Microscopic Fungi," confining his remarks to Epiphytic Fungi, and referring not only to the "alternation of generation" of some of these plants —as, for instance, Uredo and Puccinia—being various forms of the plant at different times of the year, but also to certain phenomena in the animal world to which the same name, "alternation of generation," had formerly been applied. Explaining the true nature of the latter in the case of the Aphis and Polyps, he showed the essential difference between them, and the changes observed in some Epiphytical Fungi. Mr. Leipner presented several specimens to the Herbarium.

December 16.—The subject for the evening was, "New Zealand Flax and Kauri Gum." The Honorary Secretary, Mr. C. B. Dunn, gave a succinct account of the so-called New Zealand Flax, showing by specimens received from the Orewa Flax Mills, Auckland, and by native prepared Flax, that *Phormium tenax*, (var. Tihore) produces a fibre of great strength, and when well prepared, is of a beautiful glistening appearance, and very soft to the touch. Phormium belongs to the natural order Liliaceæ. Dr. Hooker says, "There are two species, viz., *P. tenax*, seed-pod erect, 1½ to 3 inches long, straight, leaves very strong; *P. Colensoi*, seed-pod pendulous, 3 to 7 inches long, twisted, leaves weak. The former grows to 15 feet, the latter to 7 feet high. In the Province of Auckland the former abounds, and there the manufacture is a success; but in the South Island the latter abounds, and there the manufacture is a failure. The fibre is obtained from the leaf, the vascular tissue running continuously the whole length. The leaves average 5 feet, and in appearance are not unlike the common flag, *Iris Pseudacorus*, of our marshes." The various modes of manufacture were then described, from the scratching with the nails by the Maori to the most approved machinery. The principal use the fibre is adapted for is that of the manufacture of rope, it being equal to Manilla, and considered by some to be stronger.

Mr. Dunn then took up the second subject on the notice paper,

"Kauri Gum." This Gum is largely imported from Auckland, New Zealand, and is dug up out of the ground, found on an average of 9 inches below the surface, and met with in untimbered fern ranges or swamps. The explanation of its being there found is thus given by the inhabitants: "Very large tracts of country in this Province were once covered with magnificent forests of Kauri Pine, *Dammara Australis*, attaining the height of 200 feet. When these forests were burnt the Gum (which issues from wounds in the tree, and is occasionally seen hanging like icicles from the branches) was by the action of the fire driven down, and forced its way through the roots into the earth." This is the Gum that is exported principally to England and America, and is made into carriage varnish. The best quality, however, is like clouded amber, and is, in fact, used for the mouthpieces of pipes and ornaments for ladies. It is brittle, translucent, and gives off a fragrant odour when heated. The following is the result of an examination by Mr. J. Fuller: "The Gum is a resin of sp. gr. 1.05. It is partly soluble in cold alcohol. The residue does not dissolve on heating, but appears to take a quantity of alcohol into itself, forming a viscous mass. This becomes brittle on heating, or on exposure to the air. The alcoholic solution forms a very clear varnish. The Gum melts at about 320° Fah.: the residuum requires a higher point for fusion. Forty-two per cent. of the Gum is insoluble in alcohol. The Gum is soluble in turpentine and the oils forming varnishes. It is only slightly acted on by caustic soda saponifying slowly." A lively discussion, as to the manner in which the Gum got into the ground, concluded the evening.

ENTOMOLOGICAL SECTION.

DURING the past summer, owing principally to the exceptionally wet season, only one out-door excursion was taken, on May 11th, to Weston-super-Mare, the day being very unfavourable; the captures made were very few and principally common sand-hill species. Two other excursions were planned, but bad weather prevented their being carried out.

Many interesting species, both British and exotic, have been exhibited during the year at the indoor meetings of the section. Among the British lepidoptera may be mentioned *Deilephila galii*, *Platypteryx sicula*, *Stauropus fagi*, *Dianthecia albimacula*, *Nascia cilialis*, *Mellissoblaptes cephalonica*, *&c.*, *&c.* Among Coleoptera, the best capture in the neighbourhood for the season, was one of a number of specimens of *Eros minutus*, by Messrs. E. C. Rye and Mc Lachlan, during the visit of the British Association; others were afterwards captured by members of the Entomological Section. A number of this pretty little rarity were captured some twelve years since by Mr. Edwyn Reed, also at Leigh Woods, but no additional specimens had occurred until Messrs. Rye and Mc Lachlan re-discovered it.

In August, Mr. J. T. H. Preston captured a specimen of *Euperia fulvago* at Fishponds, and exhibited it at the October Meeting of the Section—this capture is interesting in being the only recorded occurrence of this fine species not only in the Bristol District, but also in the West of England.

At the October Meeting of the Section, Mr. A. E. Hudd read the following note on *Solenobia pomonæ* and *Xymastodoma melanella*.

"Some years since, in 1869, Mr. Harding published in the Entomologists' Monthly Magazine, Vol. VI., pp. 91-93, some notes on these species, in which, from the fact of having bred both forms

from cases collected from the same trees, it was suggested that probably both forms were in reality only one species; and, that in fact, what had previously been known in England as *Solenobia Pomonæ* was, in reality, only an apterous form of the female of *Xymastodoma melanella.*

This startling theory naturally caused great surprise at the time among Microlepidopterists; but, although more than six years have since elapsed, no one has, so far, attempted any explanation of the facts contained in Mr. Harding's paper until quite lately, when Mr. Boyd, of Cheshunt, has taken the matter in hand. This gentleman has kindly forwarded to me a paper on the subject which he has prepared for publication in the next number of the magazine, in which paper I think he has quite proved that the two forms are not of the same species.

The apterous females belong to a species of Solenobia which is at present only known in that form; they emerge from cases differing from those of X. melanella, and in emerging leave their pupa skins inside the case which they never entirely forsake during their short lives, resting generally with their long ovipostors concealed in the mouths of their larva cases.

Both sexes of X. melanella on the other hand, not only emerge from their cases, but draw out their pupa skins with them, the wings of the female being as fully developed as those of the male but rather narrower.

Cases and images of both forms were exhibited from Mr. Boyd.

Mr. Harding in reply said, the subject brought forward by Mr. Hudd was one surrounded by difficulties, and that much could be said on both sides of the question. He had long been aware that some of the cases were more or less three sided, while others, even cone shaped, and even if it was conceded that the more angular cases always produced the winged form, while the more cone shaped ones produced the apterous female, still nothing could be proved conclusively from this—the great difference in the forms to be produced would quite explain the slight differences in the cases.

With respect to the other point which Mr. Boyd and Mr. Hudd seemed to consider quite conclusive, viz., that the winged forms in emerging from their cases dragged out with them their pupa skin—nothing conclusive can be proved from this fact if all the circumstances are taken into account. In the one case you have a fully developed, vigorous insect, and in its struggles to get free, the pupa skin is dragged out of the case either fully or in part. On the other hand, the apterous form is most sluggish, and is not only quite wingless, but almost legless: the wonder to me is not that it does not drag out its pupa skin, but that it is able to emerge at all.

There is now no question at all that these singular apterous females have in themselves the power of re-production for several generations at least; but I certainly am not prepared to admit that they have the power of continuously re-producing themselves—a conclusion to which we seem to be driven if S. Pomonœ is a true species—since I first discovered this species, some fourteen or fifteen years ago, I think I may say, positively, that no male form has appeared, that is if Pomonœ is not a form of Melanella. It is a question full of interest; and, now, that Mr. Boyd has again drawn attention to the matter, it is to be hoped that it will not again be lost sight of until the singular economy of these insects is conclusively worked out.

At the December Meeting of this Section, the Chairman, Mr. S. Barton, called the attention of the members to the lamented death of Mr. Sanders, and a motion was carried expressing the sorrow of the Entomological Section at the great loss sustained by the death of the President.

Mr. W. H. Grigg then read some further notes on *Platypteryx Sicula*, and reported the capture of three additional specimens on the 23rd, 24th, and 26th of June. He also mentioned, as of greater interest, the fact of the larva of this insect having been discovered; one specimen of the caterpillar was beaten from lime by Mr. Thomas, on September 11th, and was at once forwarded to Mr. Buckler for figuring, and this had been satisfactorily acc omplished.

GEOLOGICAL SECTION.

FEBRUARY 10th, 1875.—The Annual Meeting of the Section; the President and Secretary were re-elected. Mr. E. Tawney proposed that instead of giving a guinea to the Parent Library, some geological work should be purchased by the Section in future and presented. This was the only evening Meeting of the Section, such geological papers as were produced by members having been taken to the General Meetings.

May 18th, 1875.—The first excursion of the Section was on Whit-Tuesday. As usual, the whole of the day was devoted to this purpose, and the goal was the neighbourhood of Ilminster. The party, consisting of nineteen, left by the 8.10 train, the manager of the Bristol and Exeter Railway having courteously placed a broad-guage saloon carriage at their disposal. On arriving at Ilminster, vehicles were in attendance in order to take them over the ground more rapidly. The first sections visited were those of Herne Hill, where the Upper and Middle Lias is well seen; driving thence through the villages of Donyatt and Seamills they reached the Moolham Quarries, where a further search for fossils was made. From here the road was taken through Kingstone to Shepton Beauchamp and through a charming country overlooking Seavington, rich in orchards and picturesque lanes. Thence through the village of Barrington, with its interesting church, to Barrington Hill, which was ascended on foot; after the quarries there had been well explored, the carriages were regained, and return was

made through Packington to Ilminster. A halt was made at the hotel for dinner; the church was afterwards visited, and finally departure made for the train (6.45). The weather was all that could be desired, and in every way the expedition was most successful.

Owing to the visit of the British Association in August last, and to the preparations necessary for it, the ordinary excursions were a little interfered with. Consequently the following was the only other one of this Section :—

September 29th, 1875.—A small party started by the one o'clock train for Yate; they walked by road to Yate-rocks through "Goose Green." The Carboniferous Limestone was found exposed in quarries with very pronounced vertical joints, always simulating bedding, so regular was the division into masses of a foot thick or so; the joints were E and W; the bedding was at an angle of 15°—20°. A curiously laminated condition of the Magnesian Limestone was found in blocks reposing against the Carboniferous Limestone. Barytes is said to be worked in the red ground out in the valley below.

Obituary.

Our lamented President, the late W. Sanders, F.R.S., F.G.S., who died Nov. 12th, 1875, was born January 12th, 1799.

From early years he took to the study of mineralogy and geology, and for about 50 years he superintended these departments in the Bristol Institution. His name appears already in the first few years after its foundation, (1824, &c.,) as a donor to the collections, and 1827 he took the Hon. Secretaryship of the Museum sub-committee, and continued as such to direct the Museum affairs till 1856; when there being no longer any Curator, the title was made for him of Hon. Curator. On the amalgamation of the "Institution of the advancement of Literature, Science and Art," with the "Bristol Library Society" in 1871, he became a Vice-President of the joint Society, as well as Hon. Curator of the Museum, and continued to give the greater part of his time to working for it and watching over its interests.

In 1845 we find him occupying the place of joint Secretary of the "Philosophical Society" which used to meet at the Institution for their evening Meetings, and this office he kept till the Society gradually died out, and its place was taken by the Naturalists' Society, the field-meetings of which were more in harmony with the active spirit of the age. Of the latter Society he was one of the originators, and has been annually re-elected President from the commencement.

His earliest published work seems to have been a short pamphlet on the crystalline form of Celestine from Pyle Hill, Bristol, worked out according to Brook's method which was then in vogue.

During the making of the Great Western and Bristol and Exeter Railways, he surveyed the whole of the cuttings between Bath and Bristol, and thence to Taunton, laying down to scale the whole of the different beds, showing their true dips, thickness, &c., copies of this manuscript section are preserved in the Mining Record Office.

Travellers on the Great Western Railway may notice near one of the tunnels close to this city, a large spherical mass of ferruginous rock placed on a pedestal of masonry; this was there placed at Mr. Sanders' expense, he having obtained permission from the engineers to preserve this concretion which came out of the Pennant Sandstone.

His intimate knowledge of the geology of his native town, was early of use to his fellow citizens. In the Parliamentary enquiry into the health of Towns Commission in relation to visitations of cholera he assisted Sir H. De La Beche, contributing the coloured geological map of Bristol and a horizontal Section through Bristol and Clifton showing the geological structure of the ground on which the city is built. This was printed in the "appendix to the second report of the Royal Commissioners of enquiry into the state of large towns and populous districts," (1844-5,) together with some geological details as is there acknowledged (*ibid.* Report on Sanitary Condition of Bristol, pp. 8-9.) Subsequently he contributed similar matter but somewhat extended, to the "Report to the General Board of Health on a preliminary enquiry into the sewerage, drainage, and supply of water, and the Sanitary condition of its inhabitants," by G. T. Clark, superintending Inspector for Bristol, (London, 1850.) For this work four horizontal Sections were run through the town, geologically colored, and the geological map as drawn up by him again added.

The following papers were contributed by him to meetings of the British Association:—In the year 1840, "Account of a Raised Sea-beach at Woodspring Hill, near Bristol." In 1841, "Notices

of Sections between Bristol and Bath, a distance of twelve miles, prepared by direction of a Committee of the British Association." In 1846, "On Railway Sections on the line of the Great Western Railway between Bristol and Taunton." In 1849, "On the Age of the Saurians, named Thecodontosaurus and Palæosaurus."

He early formed a friendship with the late Professor J. Phillips, and accompanied him and Sir H. De la Beche during a part of their work in Devonshire, about 1835. In 1844 he went to Switzerland to renew his acquaintance with Agassiz and study glacial phenomena; he stayed some days at the Grimsel Hospice in company with Professor Desor. During the same trip he met Professor J. Forbes on the Mer de Glace, and had the advantage of seeing the results of his observations.

We have now to mention his *Opus Magnum*—what may be almost said to have been the work of a lifetime—viz., his large geological map of the Bristol coalfields. He began a geological map of the environs of Bristol, perhaps about 1835; he seems to have worked originally on large-scale maps, transcripts of parish ones, and, as Sir H. De la Becho was soon after that time working for the Government Geological Survey in the district, he seems to have copied the boundary lines on the one inch ordnance map and presented his results to the National Survey. His name appears accordingly on the Bristol sheet of the Government map. His friend, Sir H. De la Beche, however, persuaded him not to abandon his work on the large scale, which admits of much greater accuracy of delineation, but to continue it and publish it. This object he seems to have kept before him, and after more than twenty years of work he finally accomplished it; the large map of the Bristol coalfields, on a scale of four inches to the mile, was finished in 1862. It contains over 720 square miles of country, reaching from Wells on the S., to Berkeley on the N., and Bath on the E.; the geological lines are all from his own surveys, on which he bestowed most scrupulous care, and it may be truly said that no single amateur has ever produced such a work on his own resources. The topographical basis of the map too had to be reduced by

collating some hundred parish maps of many different scales; this was done at his own cost and under his own immediate revision. Topographically considered even, the map is a work of great usefulness.

About 1863 his summer trip was spent in the Snowdon district, and he has more than once related to us how, when he was hammering out fossils near the top of Snowdon, he was accosted by the Duke of Edinburgh, who happened to be making the ascent, and asked him what he was looking for, and whom he at once initiated into the delights of his own favourite science.

In 1864 he was elected a Fellow of the Royal Society of London, in recognition of his valuable geological surveys.

His discoveries and expositions to the Geological Section of our Society will be in the remembrance of many.

In 1852 he was elected one of the Trustees of the Bristol Charities, and as such he continued to serve till his resignation in the summer of 1875 through failing health; he devoted himself with great zeal to the work, taking especial interest in the educational foundations.

In 1865 he became a Director of the Bristol Water Works Company, and continued one till the end. From 1838 he had been one of the Directors of the Savings' Bank, of which his father was one of the chief originators.

As a private friend his loss is mourned by many. To local students of science it is no less a grievous one. One trait of his character was his great modesty; although his local geological knowlege was so profound, he always listened with interest to the questions of beginners, and made them almost feel that they were supplying him with information, while he was gradually removing their difficulties. Other pages of this volume bear witness to the sorrow of the members at his decease.

E. B. T.

ERRATA TO VOL. I.

Page 11, line 12, column 2. For "reticulata" read "sub-reticulata"
..... 13, ... 3. For "in the state of," read "in the present state of."
...... 23, ... 11. For "Murchisoni," read "Murchisonæ."
.. ... 42, ... 13. For "greatest height," read "greatest breadth."
...... 97, ... 11, from base. For "acerasum," read "acerosum."
...... 101, ... 2 and 4 from base. For "Tetnemorus," read "Tetmemorus."
...... 110, ... 15. For "Combrash," read "Cornbrash."
.... 16. For "Finest," read "Forest."
...... 111, ... 19. For "realy," read "really."
...... 127, .. 8. For "Arancida," read "Araneida."
...... 138, ... 7. For "Vestebra," read "Vertebra."
...... 139, ... 7. For "Aricula" read "*Avicula.*"
.... 15. For "unless the circumstances," read "unless these circumstances."
...... 140, ... 4 from base. For "at the top," read "at the base."
On plates 4 and 5, read "Vol. I," for "Vol. II."
...... 147, ... 13 from bottom. For "461, 22," read "vol. 161, p. 511."
...... 148, ... 6 from bottom. For "have," read "has."
...... 170, ... 5. For "*Spiriferini,*" read "*Spiriferina.*"
...... 170, ... 6. For "*Gy,* read "*Gry.*"
...... 171, ... 7 from bottom. For "position," read "condition."
...... 172, ... 18. For "*variablis,*" read "*variabilis.*"
...... 172, ... 10 from bottom. For "clayshell," read "clay-shale."
...... 178, .. 12 from bottom. For "*Pleuratomaria,*" read "*Pleurotomaria.*"
...... 182, ... 6 from bottom. For "5″ 6‴" read "5′ 6″"
...... 184, ... 7 from bottom. For "remaked," read "remarked."
..... 187, ... 13. For "phosphatical," read "phosphatised."
...... 194, ... 16. For "*ven lencophœa,*" read "*var leucophæa.*"
...... 199, ... 2. For "Tissidens," read "Fissidens."
...... 206, ... 21. For "problems,' read "problem."
...... 210, ... 32. Cancel the whole of the line.
...... 210, ... 33. For "the," read "The."
...... 211, ... 5. For "lineal," read "linear."
...... 211, ... 12. Ditto ditto
...... 211, ... 6. For "sum," "sum," read "product," "sine."

ERRATA.—*Continued.*

Page 213, line	1	For sentence beginning "on the other hand," read "on the one hand, there must be taken into account the changing and constantly lessening divergence of pencils of large apertures after entering the objective: on the other hand, the opposite condition, &c."
...... 216, ...	17.	For "in," read "on."
...... 217, ...	4.	For "two first," read "first two."
...... 217, ...	21.	For "every improvement," read "every later improvement," and cancel "since."
...... 218, ...	7.	For "affected," read "effected."
...... 219, ...	27.	For "as," read "and."
...... 221, ...	16.	For "in the," read "IX. In the."
...... 222, ...		In note, two lines from bottom, for "Roberts'" read "Nobert's."
...... 228, ...	9.	For "refracted," read "refrangible."
...... 229, ...	28.	For "thing," read "things."
...... 230, ...	12.	For "So long as the angle, &c." read "As long as the size of aperture remains so large that, &c."
...... 230, ...	29.	For "definite kind," read "prescribed form."
...... 231, ...	8.	For "illuminations," read "illumination."
...... 234, ...	19.	For "surface," read "surfaces."
...... 240, ...	11.	For "alteration," read "alternation."
...... 255, ...	18.	Cancel "does."
...... 246, ...	27.	For "content," read "contents."
...... 250, ...	1.	For "operation," read "observation."
...... 251, ...	18.	For "From the point, &c." read "XXIII. From the point, &c."
...... 253, ...	2.	For "content," read "contents."
...... 253, ...	5.	For "in," read "or."
...... 254, ...	20.	For "objective," read "objectives."
...... 255, ...	32.	For "pencil," read "pencils."
. ... 255, ...	34.	For "condition," read "conditions."
...... 260, ...	11.	For "partially," read "potentially."
...... 261, ...	23.	For "condensors," read "condensers."
...... 264, ...	8.	For "sound," read "sand."
...... 265, ...	7 from bottom.	For "Holapella," read "Holopella."
...... 271, ...	8.	For "Limestone," read "sandstone."
...... 277, ...	14.	For "PALMOBRANCHIATA," read "PULMOBRANCHIATA."
...... 301, ...	14.	For "*Ælcistes,*" read "*Æcistes.*"
...... 304, ...	5 lines from bottom.	For "*Fontanalis,*" read "*Fontinalis*"
...... 306. ...	10 from bottom.	For "*amygdalima,*" read "*amygdalina.*"
...... 309, ...	9.	For "*albipunta,*" read "*albipuncta.*"
...... 189, ...	column 1, line 12 from base.	For "Terebratuta," read "Terebratula."
...... 319, ...	column 1, line 12.	For "crinisria," read "crinistria."
...... 322, ...	column 2, line 12.	For "covonata," read "coronata."
....	column 2, line 9 from base.	For "oralis," read "ovalis."
...... 333, ...	column 2, line 7 from base.	For "canalienlata," read "canaliculata."
...... 338, ...	9.	For "seam," read "seams."
...... 348, ...	7.	For "centnry," read "century."

ERRATA.—*Continued.*

Page 352, line 10 and 11. For "Bex Diablercta," read "Bex Diablereta."

...... 353, ... 8. For "chose," read "choose."

...... 375, ... 18. For "L. rusticola," read "S. rusticola."

...... 384, ... 8 from base. For "discovery fossils." read "discovery of fossils."

...... 471 ... 20. For "forea," read "fovea."

...... 482 ... last line. For "nch," read "inch."

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NEW SERIES, VOL. II., PART II.

REPORTS OF MEETINGS AND EXCURSIONS.

[Authors alone are responsible for the various statements and opinions in their respective papers].

Plate IV. has been presented by Mr. W. W. Stoddart.

On the Older Rocks at St. Davids.

BY E. B. TAWNEY, Assoc. R. Sch. Mines.

Read before the Geological Section, February, 1878.

HAVING thought that it might interest the Society, I propose to give some account of Dr. Hicks' researches among the Older Rocks at St. Davids, and exhibit, at the same time, specimens which I collected there in the past summer. Our remarks will not unnaturally perhaps take the form of a commentary on his last essay* read before the Geological Society in November, 1876, in which is brought before us an account of the oldest rocks in England and Wales, and new arguments entailing new appellations to characterise their relative antiquities. We are there introduced to the *Dimetian* and *Pebidian* series, which are far older than,—being unconformable to the oldest fossiliferous series,—the lowest Cambrian. To these our observations will be chiefly confined, for they are the latest acquisitions to science in that area. Not that Dr. Hicks' researches have been confined to them,—they are newest because they have been taken last.

* On the Pre-Cambrian (*Dimetian* and *Pebidian*) Rocks of St. David's, by Henry Hicks, M.D. Q. J. G. S. xxxiii., p. 229, [1877.]

By looking through the last few volumes of the Quarterly Journal of Geol. Society, a series of papers will be noticed on various fossiliferous members of the Cambrian series. The faunæ have been described in turn by Dr. Hicks from the Arenig, the Tremadoc, Lingula beds, Menevian, and so forth down into the lowest Cambrian, new forms being discovered where none were known, and life being pushed back farther and farther into the past. Below the *Conocoryphe Lyellii* beds, below the red shales with *Lingulella primæva*—the oldest fossil in Great Britain—was still a great thickness of sandstones which has yielded, hitherto, no fossils; while at the base of the Cambrian lies the great conglomerate, intensely hard, red in colour usually, and formed of rolled quartz or quartzite pebbles mainly, most firmly cemented together. This massive rock breaks off, at the out-crop, in blocks weighing several tons usually; it constitutes, therefore, a well marked base to the Cambrian. With these sedimentary and unaltered beds we have not now to concern ourselves, but below all this Cambrian, and partly concealed by them, come in the Pebidian and Dimetian series—the Pre-Cambrian beds.

I enjoyed the great advantage of being taken over a great part of the ground by Dr. Hicks himself, who most courteously showed the most fossiliferous places in the sedimentary, and in the crystalline series demonstrated the sections especially noticed in his paper. In collecting, therefore, I knew that I was dealing with the same objects referred to by Dr. Hicks.

From the history of his researches given in his introduction to his last memoir, we note that the idea of a Pre-Cambrian period was enunciated in 1864 (*loc. cit.* p. 229) in collaboration with Salter.

Immediately under the city of St. Davids is a ridge of crystalline rocks—mapped as Syenite by the Geological Survey,—this was the Pre-Cambrian Island. It has been the subject of Dr. Hicks' examination, from time to time, during the last fifteen years.

His latest description of the Pre-Cambrian divides them into

two distinct series, Dimetian or lower, and Pebidian or upper series. The chief point of this distinction lies, I think, in the admirable way in which has been shown by careful survey and as careful reasoning, that these are in fact two separate series, unconformable to each other, as they are both to the Cambrian which overlaps them indifferently. These points seem to have escaped previous observers; indeed they seem to require such intimate knowledge of the ground for their appreciation, that they have not been unreservedly accepted. The matter is so comparatively new that there seems still room for further research and discussion.

The few remarks which I have to make are founded on the examination of the crystalline rocks which were collected carefully in place, with a view to subsequent examination by the microscope. I should state at the outset that I provisionally accept Dr. Hicks' conclusions, though the microscope examination leads me to look upon some of the rocks rather differently,—too minute a criticism it may be said if it does not alter the outcome of his contentions.

Dimetian. The rocks which compose this series are said to be "chiefly compact quartz schists, chloritic schists, and indurated shales," [*loc. cit.* p. 231]. They are all considered to belong to a metamorphic series. Dr. Hicks notices their change in character from N. of St. Davids, where they are said to be more highly crystalline, towards the S. where they are less highly metamorphosed. At Porth Lisky they are termed quartz-schists. There is thus a change along a N.E.—S.W. direction—according to our author the direction of dip of the old series,—which by metamorphic action have become the now highly altered Dimetian. This change, along a determinate direction (dip), and constancy of character along the strike, is a most important point, and fully proves, I fancy, if we accept the facts, that the so called Syenite of former authors is not an irruptive rock, but truly metamorphic. The discovery of the metamorphic nature of the lower Pre-Cambrian series seems to me a most interesting point. The history of the existing sedimentary series, of which we see now

only the metamorphosed remnants, is, of course, a subject only of speculation.

I have now to enumerate the specimens collected from this series.

Brynygarn Quarry. The rock here, about a quarter of a mile S. of the city, is a massive crystalline rock of granitic or coarsely crystalline character, not compact therefore, but granular or phanero-crystalline,—a mixture of pale pink, greenish and colourless constituents. Microscopical examination shows it to consist of *Felspars*, chiefly Orthoclase, a little banded plagioclase is seen attached to one or two of the others: many are much attacked by decomposition, becoming granulated and only semi-lucent; others, though somewhat clouded, show vivid colours on revolving prism. *Quartz* very abundant, irregular masses contiguous to each other, or between felspars, &c., very full of minute fluid-cavities with moveable bubbles, scattered or arranged in strings. *Chloritic* constituent, probably the remains of hornblende though not preserving its form, is partly dichroic, and remains dark blue under crossed prisms, while part has quite lost its depolarising powers (viridite). In some cases decomposition has gone further, and it has become mixed with *Epidote* and a black opaque substance for which we may use the term *Opacite*. There is no mica. A similar rock is seen on the opposite side of St. David's Valley near Clegyr Foia Road: it seemed not necessary to have it sliced for the purposes of this preliminary examination, nor was the rock near Porth Clais and other places where it presents the typical appearance so treated. In this quarry the Dimetian is pierced, as I take it, by thin green bands of a doleritic rock which has been introduced along divisional planes, whether of original bedding or mere joints I could not here determine. There are two bands in this quarry, the upper one of only a few inches—near the surface of the ground—it thins out entirely on one side, and not only so, but it is highly decomposed, being converted and running down into a mere sandy earth: it

differs only from analogous dykes on the road to Porth Clais in being not vertically irruptive, but inclined at the angle of the divisional planes. The second band in the quarry is thicker. It was found less decomposed, but with a fracture, reminding one of trap—sub-columnar distinctly,—and lying between irregular walls with re-entering angles, and apparently injected therefore with force. These bands were classed originally, in the paper referred to, as "ashy shales," supposed to be interbedded in a metamorphic series. There are chemical doubts which would arise—besides the geological ones—as to the possibility of a thin bed of basic silicates a few inches thick being enclosed between two masses of acidic rock with much free quartz, without an intermediate passage or obliteration of the basic characters, seeing that the metamorphic action would affect both. These green bands are acknowledged I believe by Dr. Hicks, in a later paper now in the press, to be of igneous nature, on hearing from Professor Bonney that the one at Porth Lisky, which he examined microscopically, is a dolerite. For my part I hold them all to have been introduced subsequently to the metamorphism of the Dimetians. As to their age, they may perhaps have been injected during the Pebidian period, for there are somewhat similar green basic rocks in that series near Rhosson Rock, &c., but this is a point for further research.

Having begun the question of intruded rocks, perhaps it will be well to notice some other cases before continuing the consideration of the metamorphic (Dimetian). The case of a vertical dyke has been noticed by Dr. Hicks (*loc. cit.* p. 234), and described by Professor Judd (*ibid.* p. 235, note) as a melaphyre or altered dolerite. It is a green basic rock, and its decomposition—not to be wondered at seeing its great age—I believe to be due entirely to infiltering waters, because we find that the narrower the dykes the more decomposed they are; *e.g.*, there is close to the main dyke at Porth Clais, a few yards to the W., another about six inches wide, but vertical in position: evidently connected with these are, on the roadside section a few yards up the road, other

little strings of green rock, not vertical, but intruded along the joints of the massive Dimetian; they are so thin that they have become quite decomposed, and run down to a green sandy earth; they would probably have passed unnoticed if unmistakeable dykes had not been seen in their vicinity. A microscopic slice was taken from the 1½-foot vertical dyke for comparison with the other cases of supposed chloritic schists or indurated shales which are noticed below; its structure has been already described in the memoir above cited.

On the coast at Porth Liskey a dyke has been noticed by Dr. Hicks (*l. c.* p. 235) which is vertical, and shows horizontal columnar structure. Close by are thick masses of green rock, which are described by their discoverer as chloritic schists, effervescing with acids, and containing some of them over twenty per cent. of carbonates. It appeared, however, to Mr. Huddleston and to Professor Hughes, our companions, that these were better to be interpreted also as dykes. Certainly the appearance in the field seemed to show that this was the more likely explanation as they break about irregularly, at one time horizontal, at another spot arching up towards the before-mentioned vertical dyke, with which they are probably united either above or below—these portions show no columns. For microscopic study, slices were taken from both the vertical columnar dyke and the thick inclined mass of green rock. The structure was found identical, and tallying also with that of the Porth Clais dyke. The Calcite is in crystals, polysynthetic, and evidently of secondary origin. As the felspars have been decomposed so the calcite has been deposited. The bisilicate has been entirely replaced by Viridite, not even any crystal form having been preserved. Opacite in cubical masses and grains is abundant.

For the preliminary notice as above cited, Dr. Hicks has, I believe, substituted in a forthcoming paper another in which their igneous origin is assumed. He speaks above (*l. c.* p. 234) as if the vertical dykes "had been intruded into the series before this

was elevated out of the horizontal position, and before metamorphism had taken place." That is not our view: we hold that they are not metamorphosed* but injected, subsequent not only to the consolidation of the rocks, but to the date of their metamorphosis.

A thin slice made out of a piece showing actual contact of the Dimetian, and one of the purplish-green bands, showed no apparent alteration in the massive rock, while the felspars of the dyke in thin long prisms were alineated nearly all in one direction, the result apparently of fluid-motion along the face of the containing wall. For the piece whence this slice was taken I am indebted to the kindness again of Dr. Hicks.

If we may take it then as proved that these green bands are intruded, it is interesting to notice that these inclined with the dip or joints, and having entered along such planes, are far more numerous and persistent over the whole region than those dykes of similar rock which occupy vertical fissures. They show the

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* The word metamorphic is used in so many senses that misconception may easily arise from its use. Changes which ensue in rocks may, for illustration be roughly grouped as (1), due to air or moisture, infiltering waters, &c.: to such we conceive the superficial weathering of rocks near the surface to be due, and here we place the ordinary chemical re-arrangements in the dyke above noticed. (2)—Local alteration due to heated intrusive rock, "contact alterations,"—we would plead for the disuse of the term "contact metamorphosis." (3)—The alteration in rock, to which alone I could restrict the term metamorphosis, viz., that to which the crystalline schists and some granites are due (Metapepsis of Kinahan): its causes perhaps are hydrothermal, but the exact conditions are not universally agreed upon, so that we may note its conditions as more or less indeterminate, but extending over large tracts, while the action of the two former is local and limited in extent and their causes more explicable. This distinction of terms has been previously suggested in a similar sense by Mr. G. Kinahan (see Trans. Edinburgh Geol. Soc., Vol. III, p. 59, 1877.) Since, in the expression "metamorphic" rocks, this technical meaning is already conveyed, it seems to cause useless ambiguity to use "metamorphism" for cases where the ordinary words, 'change,' or 'alteration,' would be more fitting.

lines of least resistance—in other words—the Dimetian was consolidated, and had assumed its crystalline aspect and present system of joints before the basic rock was intruded.

Near Porth Lisky, Dr. Hicks also pointed out to us the limestones described by him (*l. c.* p. 232) last year: he showed us that most of them were inclined in the same direction as the crystalline schists in which they were intercalated. But one at any rate at one place dipped in an opposite direction, as if there had been an anticlinal. We could discover however no proof of an anticlinal in the crystalline rock, and we are disposed to seek for another explanation of the bands of limestone. We notice that the texture of this limestone is coarsely crystalline, and the band contains much serpentine in blotches and streaks. We suggest that it is not likely that these thin bands with crystals of dolomite, calcite, &c., as described in Mr. Huddleston's analysis, could be of anything but of secondary origin in a metamorphic series enclosed between walls of such an acidic rock as in the Dimetian here. The thinness of the bands, one to three feet, seems to render it possible that their orign is due to the decomposition caused by water filtering down joints, removing alkaline silicates and depositing carbonates of lime and magnesia; the presence of serpentine too may be held to strengthen this hypothesis. The percolating waters would have taken the direction of the main divisional planes, which are here the ancient bedding as a rule, while in the one exceptional case they may have followed one of the other system of joints, and thus a calcareous band have been formed dipping apparently in an opposite direction. This explanation arrived at in the field seems to agree with the described chemical and microscopical analyses of the rock by Messrs. Huddleston and Davies (*l. c.* p. 234, note).

A few words on the Dimetian rock at Porth Lisky, the microscopic structure of which was described by Mr. Davies (*ibid.* p. 231, note). It is said in places to contain very little felspar. No doubt this is true, but such a state is perhaps

exceptional. The bulk of the cliff section shows felspar to the unaided eye, but it is apparently more translucent and less opaque than at St. Davids, the quartz may be more abundant in proportion and the chlorite less than at Porth Clais, St. Davids, &c. In the thin section which I had made for the microscope both Orthoclase and Plagioclase are present. The Quartz contains liquid cavities. Microscopically the appearance of the rock is noted by Dr. Hicks as emphatically different in this higher portion of the series from what it is lower down: this harmonises with the idea of the metamorphic origin. The rock has much more tendency here to schistosity or obscure lamination than elsewhere, its fracture under the hammer being markedly different here to what it is nearer St. Davids city; it splits into flaggy and rhomboidal pieces owing to concealed laminæ coated with a chloritic thin lining—along these planes the rock parts. The bedding planes are well marked while elsewhere it is difficult to say which divisional planes are dominant, or less irregular than the others.

The Dimetian immediately N.W. of the city may next claim our attention: we are here close to the fault which runs down the valley bringing Pebidian against the Dimetian, with as Dr. Hicks has shown, a difference of 90° in the strike of the two formations.

The quarry below the Board-school is nearest the fault, and shows us the lowest beds of the Dimetian. The quarry is disu sed and matters are not as clear as one would like; it seems to me however, that we have there three distinct rocks; (1), at the left a fine grained greenish and blue-grey rock, which is probably Dimetian in a somewhat altered condition; (2), a dyke of green basic igneous rock, nearly vertical in position apparently and much decomposed; it is only seen at the left of the excavation forming the face for a small area only, behind it is (3), a quartz porphyry, this I state to be an irruptive rock; the section in its present state does not show the relations of the three rocks as we could wish, but from various considerations I interpret them as above, viz., the Dimetian altered by the intrusion of the quartz-

porphyry, which must have flowed over or through it subsequently to the metamorphism of the former. There would be thus a considerable interval between the Dimetian and the porphyry: the latter, perhaps, may be of early Pebidian age. The basic dyke was probably subsequent in date to the porphyry, and may be of late Pebidian age, since that series contains green basic rocks, probably contemporaneous flows intermingled with bedded ashes or ashy shales, and as before stated, they are subsequent to the metamorphism of the Dimetian. They might of course be long subsequent to the Pebidian, but we have not noticed them in the Cambrian, the intrusive rocks of which are of different character so far as we know.

A thin slice was prepared of the quartz-porphyry. To the unaided eye it is a pale greenish-grey rock, weathering slightly reddish from oxidation; it contains double pyramids of quartz with rounded edges generally; they drop out of their nidus with facility, leaving impressions of the hexagonal pyramid; they are surrounded with a white layer having an incipient sphœrulitic structure. The rock in colour is not very different from the Dimetian, but differs plainly even to the eye, as to texture. Under the microscope the appearance is totally different, viz., as follows:—

Sphœrulitic porphyry from Board-School quarry. The spheres are free, or interfering sectors sometimes formed round quartz nuclei which are obscure dihexahedra, with rounded angles for the most part; the radiating fibres polarise; quartz nuclei usually, when present, cause those spheres to be larger than the others.

A mineral in diverging irregular prismatic form, pale greenish-yellow in colour, but polarizing a vivid green and crimson, I take to be *epidote*; it is abundant—apparently not dichroic in this case: we meet with this product of rearranged constituents in other cases as will be noticed. *Viridite* is also present and in some cases has retained the form of augite prisms; but is converted into a fibrous state, and has lost the polarising power. A few acicular prisms, as of *apatite*, are present.

The *felspar* is much attacked, and contains particles of the green brightly polarising epidote constituent. The twins are of the orthoclase type. No plagioclase noticed in our slice.

Quartz is abundant both as irregular shapes, or dihexahedral crystals producing rhombic, or hexagonal outlines : it contains lines and scattered grains of liquid-enclosures ; sometimes a process of the ground will protrude into the crystal some way.

Similar rocks are seen in a quarry about 100 yards distant, close to the Church-school. Here is the fine-grained Dimetian again it is very tough, but contains cavities, and seems to me to have been altered by contact with the porphyry ; it is finely granular instead of being coarsely crystalline as is its wont. The mineral constituents remain, however, the same. This fine-grained rock has a micro-granitic structure : a finely granular crystalline ground with scattered larger felspar crystals ; there is a somewhat peculiar jagged interlacing, almost obscurely radiate arrangement of the ground : this may be probably due to contact with the porphyry adjacent. On the other hand it may possibly be an intrusive felsite ; but the quartz is not dihexahedral.

The *felspar* crystals are orthoclase much decomposed, a little plagioclase being present also.

Viridite is present, and is covered sometimes with red spots as of ferric oxide ; also grains of magnetite are scattered throughout. The *epidote* constituent also in small quantities, and as in the other cases seems of secondary origin.

Quartz is in irregular angular shapes, not of large size—no separate regular formed crystals present ; it contains fluid enclosures, and portions of the ground.

The top of this quarry is occupied by a porphyry similar to the last-named, except that it is much coarser grained. The dihexahedral quartz are very large crystals ; the colour and aspect to the eye is much that of ordinary Dimetian, owing to its coarse crystallization ; it is distinguished, however, by the character of the quartz. On the spot, one classed it as intrusive, as I have not

read of this quartz occurring elsewhere. The microscope shows that it has the incipient sphœrulitic structure, but not quite so well developed as in that in the other quarry. The spheres of radiating fibres are usually formed round the large dihexahedral quartz crystals which act as a nucleus, and sometimes around a felspar one: in these cases they are not fully formed, but the fibrous border consists of several interfering sectors. This example differs thus from that in the other quarry by the frequency of a large crystal nucleus to the spheroidal structure, and the non-completion of the sphere usually. Microscopically the rock also differs from the large size, and great abundance of the quartz double pyramids. When the rock is broken with the hammer they drop out, leaving quite sharp impressions of pyramid form.

The *felspar* is orthoclase, crystals much decomposed, as might be expected in such old rocks, especially near the surface: strings and fibres of *opacite*, and particles of calcite and epidote formed in the altered parts.

Viridite is present, as in the other cases, in scattered flakes and in spots on the decomposing felspar, also occasionally within the quartz; it has no depolarising power; it is partly accompanied by *epidote* particles. The quartz is full of strings of liquid-enclosures crossing in all directions.

In another quarry below the Church-school towards the cathedral is seen, again, one of the green basic dykes intercalated in the Dimetian. A thin slice shows that it agrees with the other dykes above mentioned, in having a doleritic structure. The substance of the *felspar* is not well preserved, but the form is retained—they are probably all plagioclase. Black irregular and quadrangular grains of *magnetite* are scattered all over the slide, and from their connection with other products of decomposition in the felspar, are, perhaps, of secondary origin. *Quartz* is sparsely present but of secondary introduction, probably, being near a little vein, it contains a few acicular microlites. Two little veins of *epidote* and quartz run through our slice. *Viridite* is

abundant of fibrous character, and pseudomorphing a bisilicate probably, the polarising characters have not entirely disappeared : it is usually, however, without prismatic outline, and scattered through the ground, constitutes the chief part of the rock. Altogether the rock shows less decomposition and calcification than the vertical dyke at Porth Clais (*l. c.*, p. 235 note.)

Pebidian. This series consists of a great variety of rocks, of which many are enumerated by Dr. Hicks (*l. c.*, p. 235) ; the principal point to be noted about them is their relation to the Dimetian, their strike is the direction of dip of the latter series—a total unconformity. This result of Dr. Hicks' researches presents to us, thus, two distinct series separated by wide intervals of time.

We have spoken of the Dimetian as metamorphic, i.e., highly crystallized rocks throughout, and over a portion of the area, at any rate, showing not evident bedding enough to prevent our classing it as a massive crystalline rock. The Pebidian series, on the contrary, is not a crystalline but a sedimentary series, the bedding being perfectly plain throughout. The beds seen adjoining the Dimetian axis on the N. of the city are shales and agglomerates, ashes mixed with mud, and seemingly the product of submarine volcanos mixed with ordinary sediments. The bedding is most unmistakeable, there is no metamorphosis here, and the strata are in strong contrast to the crystalline rocks of the lower series. It does not enter into our purpose to describe the almost endless variety of this series ; sometimes coarse agglomerates, at other times fine shales. At Trevithan, &c., are green and basic igneous rocks between bedded shales, probably contemporaneous flows. At other times the shales are made up of highly felspathic materials, pale in colour as if acidic outbursts were furnishing the products spread out over the sea-floor.

One remarkable rock it is necessary to notice, viz., those beds described (*ibid.* p. 236) as "the lower of the series resting immediately on the Dimetian axis (S. side), hard, compact, conglomerates, the distinctive outline of the pebbles for the most

part lost." I was not able to find anywhere in the district a pebble of undoubted Dimetian, enclosed and worked up again in the Pebidian series, but no doubt such must exist. This bed just spoken of, is described in the later account by Dr. Hicks as an agglomerate. It consists of blocks—some of them rounded as if by water action—of pale felspathic rocks showing abundant felspar crystals of primary origin as I take it; these are mixed with a more or less dark green paste of chloritic material. The bed is very tough, the alkaline silicates so abundantly present in felspars no doubt contributing by rearrangements to cement everything together. Though the materials may be not quite in the state in which they were laid down, owing to chemical changes, the bed is far from coming under the definition of metamorphosis as restricted above. There is a thick mass of it, and it would make a highly ornamental stone from the contrasts of colour in it, but would be very hard to work. Dr. Hicks has discovered among the included blocks, some which weathered showed moniliform lines and beads; I am greatly indebted to him for a fragment. Under the microscope it is seen to be a sphærulitic felsite porphyry, and has been described by him with the aid of Prof. Bonney in his, as yet, unpublished paper. If I touch upon it, it is only to draw attention to the sphœrulitic porphyries described on the other side of the axis. It is true the block given me by Dr. Hicks is not identical, absolutely, with the rock of the School quarry; it is more perfectly sphœrulitic and shows markedly, fluidal lines. There is, however, I contend, the same composition and an analogous sphœrulitic structure. There is a probability, hence, of their belonging to the same period of eruption. In a thin slice its characters are as follows:—

Sphœrulitic porphyry fragment (rhyolite of Prof. Bonney) from Pebidian agglomerate. The spheres are small but plainly seen with a hand lens; they are aggregated usually round a granular centre of opaque material which does not polarise, the cross being well seen in the spheres: some are free from the devitrified centre, while others are almost entirely converted to amorphous granular matter.

Quartz grains, mostly of irregular form, are scattered among them in the microfelsitic ground; occupying spaces between the spheres. Some dihexahedral crystals are present, containing inclusions of ground matter, microlites and minute, perhaps liquid cavities, though a moving bubble could not be detected. Much *viridite* is present between the spheres, scattered in spots and grains throughout, and in marked linear arrangement; itself the product of decomposition, it is frequently encroached on by brilliantly polarising patches which seem to be *epidote*. Brilliant groups of epidote prismatic crystals are found, apparently of secondary origin, and formed subsequently to the viridite constituent. In some cases the epidote group occupies the centre of the decomposing felspar crystal. Scattered felspar crystals are orthoclase showing the Carlsbad twinning; one case of obscure banding would show a plagioclase crystal.

Though this does not precisely correspond as far as the fluidal disposition is concerned, the mineral composition is identical; hence, one may be a portion of a current which solidified nearer the surface, developing fluidal lines and perfect sphœrulites, that seen *in situ* in the quarry may be the deeper part of a dyke, or have consolidated further below the surface, or belong to a slightly different position of the same eruptive period, as a lava of Monte Nuovo may differ from one at Vesuvius a few miles off, and a century or so apart.

If this be allowed, we have, I think, presumptive proof of the age of the quartz-porphyries N. of the Cathedral; they would be about the age of the lowest beds of the Pebidian. Hence, if they have produced contact-alteration of the Dimetian rocks, baking, hardening them, and altering their appearance as above described, we have here corroborative evidence of a lapse of time between the Dimetian and Pebidian periods. This argument supplementary of those advanced by Dr. Hicks, is put forward with hesitation as the result of only a short investigation on the spot. Not that any further corroboration is necessary, for we may take, I think, the result of Dr. Hicks' researches as well founded.

It must be confessed, moreover, that we know another sphœrulitic porphyry of Pre-cambrian, but of Post-pebidian age, the one described by Dr. Hicks (*l. c.*, p. 236) below Nun's Well. The chief points of a microscopic examination are as follows :—

Sphœrulitic porphyry near Nun's Well. The spheres are abundant in the ground, but of small size, appearing as white grains to the unaided eye. They show the cross in polarized light, but the radiating fibration is not so well preserved as in the cases mentioned above. Altogether the rock is more decomposed; the base contains a large quantity of minute specks of the viriditic matter which has lost any polarising power. It penetrates into all the interspaces. A few cases of *viridite* pseudomorphing augite is seen, it remains dark under crossed nicols, and is partly covered with opaque black matter, magnetite?

Felspar. Both orthoclase and plagioclase are present, but much decomposed and full of splashes of viridite.

Quartz is present both in irregular layers, and larger crystals of regular form, but with rounded outline; these enclose masses of viridite, and lines of stone enclosures crossing the interior, or remaining roughly parallel to the border; similar grains are collected on the external outlines, forming a sharp border to the quartz.

This rock differs considerably in appearance from those mentioned above, having very much less quartz, it seems to have also more plagioclase. The spheres are not formed round large quartz nuclei, but independently in the ground. No epidote was noticed. Altogether it seems a less acidic rock. As it pierces the Pebidian it must be considerably newer than the block enclosed in the basal agglomerate of that series.

With the Pebidian seems to cease the era of sphœrulitic-porphyries in this district; the igneous rocks of succeeding formations are of different order. In the Cambrian near Porth Clais is intruded greenstone with no similarity to any of the older rocks. In the Lingula flags above Porthyrhaw, a felsite of which the same may be said. In the Arenigs of St. David's Head, a coarse-grained

beautiful gabbro; in Ramsay Island in beds of the same age is seen a dark grounded quartz-porphyry, quite a different type to anything piercing the older rocks.

To conclude—we may sum up the results of Dr. Hicks' researches in which we have, I think it will be confessed, a remarkable advance in knowledge, and a vista opened up to us in the rocks of St. David's, of age behind age most pleasing to the imagination of the geologist. Formerly the state of things was roughly supposed to be a Syenite ridge piercing Cambrian rocks, flanked on each side for miles, by these altered Cambrian rocks. Now we are led to see in the so-called Syenite a metamorphic series, flanked by rocks composed largely of eruptive rocks detritus, long subsequent to it in age, as the Pebidian is again unconformable, prior to, and utterly distinct from any Cambrian rock.

On Myliobatis and Pterocephala.

BY S. HENRY SWAYNE, M.R.C.S.

Read April 5th, 1877.

HAVING lately purchased for the Bristol Museum from a local fishmonger a fresh specimen of the Eagle Ray or Toad-Fish (*Myliobatis aquila*) which was believed to have been captured in or near Torbay, I think its description may be of some interest.

It appears that this fish has been considered a rather rare visitant of our coasts, but Mr. Couch in his "Fishes of the British Islands" has described his obtaining from Fowey, in Cornwall, a large purse containing a young example of this species, and also mentions that Dr. Geo. Johnson had obtained a specimen as far north as Berwick. Mr. Couch's description is copied however from

Lowe's "Fishes of Madeira," and as it differs in some particulars from my specimen I think it best to give a detailed description of the latter, with accurate measurements of it.

Body, smooth—dark olive-brown above, white beneath.

Head somewhat rounded, with curved convex snout and rising abruptly from thence to a prominent vertex or forehead extended across between the eyes.

Eyes at side of head, large and somewhat overhung by the projecting edge of head. Immediately behind each eye is a large open spiracle.

The greatest width of the body and pectoral fins 32¾ inches, at a short distance behind the head. The back at this part is somewhat raised and slopes towards the snout and the tail.

Pectoral Fins widely spread, broad and slightly falciform, the concavity being directed backwards towards the tail.

Tail, 24 inches long, at first thick, tapering gradually to a whip-like termination, with a dorsal fin situated 4¼ inches from the root of the tail, and armed with two bony spines placed just behind the dorsal fin; one of these is 3¼ inches and the other 2 inches long; both are finely serrated on each side—the serrations directed backwards.

Ventral Fins, broad, 11¼ inches across from point to point. Mouth beneath the head, transverse and protected by a large flat lip. Teeth flattened with hexagonal outline and fitted together like a mosaic pavement.

Both in the upper and under jaw there is a central row of transversely extended denticles with smaller and narrower ones quincuncially arranged at either side.

The upper set of denticles form an arc of a circle to work against the hollowed under set; width of central denticles above, 1¼ inch.

The mouth contained some broken remains of the shell of a mollusk.

Total length of body from middle of snout to tip of tail, 44 inches.

Length of body from snout to root of tail, 20 inches.

Length of tail, 24 inches.

Total width across pectoral fins, 32¾ inches.

Width of head between the eyes, 4½ inches.

It may be well to compare with this specimen one or two of allied species previously in the Museum collection.

Of these the first appears to be ***Myliobatis Jussieui*** or Zygobates of Agassiz.

In this species the head is more flattened than in M. Aquila, and the margin of the snout is straight, giving a quadrangular shape to the head.

The Pectoral Fins are narrower and more falciform than in M. aquila.

Length of body, 14 inches.

Length of Tail, 28¾ inches.

Extreme width across pectorals, 26¾ inches.

Tail, whip-like, without spine.

Dorsal fin at the root of tail.

Teeth like those of M. aquila, except that there are 3 rows of transversely extended denticles with the smaller ones at the sides.

It will be observed that in this species the shape of the head approaches that found in the genus next to be described.

The tail is considerably larger in proportion to the body, and the width across the pectorals relatively greater than in M. aquila.

The remaining specimen is one of *Pterocephala* (Couch), and there is also the head of another individual of the same genus in the collection.

In this family the head is flattened, concave in front, and has on each side a projection 2½ or 3 inches long, which has caused one species to be called the Ox Ray. This projecting horn is formed of a rolled or twisted fin, terminating in a point. The spiracles are smaller than in Myliobatis.

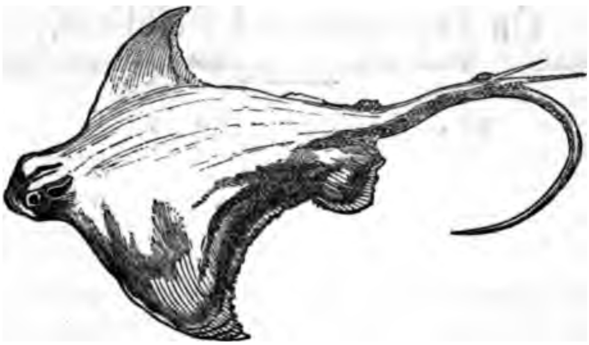
Tail, long and whip-like, without spine.

Pectoral Fins rather narrow, straight and pointed.

Teeth extremely minute, either slightly projecting and serrated or else ground flat so as to give a hexagonal outline.

One species of this genus has been called the Devil-Fish, from its repulsive appearance. From its very weak and small teeth it seems not to possess such crushing power as Myliobatis, and it probably subsists on softer food.

FIG. 1.—*Myliobatis aquila.*



On Supersaturated Solutions.

BY G. GRENFELL, M.A., F.G.S.

Read February 1st, 1877.

IN all our textbooks it is stated that exposure of a supersaturated solution to air, or contact with ordinary surfaces, will cause the solution to crystallize. In explanation of this assumed fact several theories have been advanced.

First, there is the theory of M. M. Violette and Gernez, that the crystallisation is caused by the air introducing a crystal of the same salt in the same state of hydration.

Secondly, Professor Tomlinson, F.R.S., holds that the crystallisation is caused by adhesion of the salt to a greasy surface.

Thirdly, Mr. Jeannel declared that simple contact with a solid substance causes crystallisation.

Fourthly, M. Loewel attributed it to catalysis, which may mean anything or nothing, and is in fact only another way of stating that we know nothing about it.

Lastly, it has been suggested, though not established by any conclusive experiment, that absorption might be the cause of the crystallisation.

I propose to show that neither exposure to air nor contact with ordinary substances causes crystallisation in the great majority of cases; that the theories of M. M. Violette and Gernez and of Professor Tomlinson are only applicable to a very limited number of cases; that the contact theory of Jeannel breaks down utterly; and lastly to give abundant experimental proof that the absorption theory explains a great many cases of crystallisation.

(1.) Air and ordinary substances do not generally cause supersaturated solutions to crystallise. There is a very large number of supersaturated solutions of salts of various kinds on the table, all uncovered, they will remain liquid until I purposely make them crystallise. Drops of these can be put on glass plates and on various substances without their crystallising. They can be rubbed with the finger, or with oil, or treated in various ways, still remaining liquid. This method of working with drops is quite new and is extremely convenient. A number of drops are put on a plate, and a great many experiments can be tried as to the effect of different substances. The trouble of boiling is thus reduced to a minimum. The way in which the statement given above has got into our textbooks can be explained thus. When I first began working with these solutions I adopted the plan recommended in the books of covering the solutions, after boiling, with cotton wool. Under these circumstances removal of the cotton wool generally caused crystallisation. But I noticed that the cotton wool was often sticking to the mouth of the flask, and it struck me that very probably in removing the wool small portions were detached and fell in and caused crystallisation. I then tried paper and tinfoil, and found that these could be removed any number of times without causing crystallisation. After boiling has ceased a good deal of spurting goes on for some time, the ascending currents of air are seen to contain many little bubbles or drops of the solution, and I have little doubt that these crystallise on the under side of the cotton wool and are shaken in when this is removed. It is also possible that the fragments of cotton wool cause crystallisation by absorption.

(2.) *The theory of M. M. Violette and Gernez.*—This is the theory most generally adopted. There are several *a priori* objections to this theory. We are asked to believe that the air everywhere and always contains crystals of all those salts which form supersaturated solutions. This is exceedingly improbable, because some salts form supersaturated solutions which cannot exist in air; others again such as acetate of uranium are so rare that it is inconceivable that they should be everywhere present. Besides, if the salts which form supersaturated solutions are everywhere present we must conclude that all other salts are present also. The presence or absence of a salt does not depend on its power to form a supersaturated solution. We should have to infer then that the air and dust is a most extraordinary storehouse of crystals of all kinds, which have never indeed been seen, but whose presence is shown by the fact that when the cotton wool is removed, or when a supersaturated solution is touched with a rod drawn through the fingers it very often crystallises. This theory is supposed to be strongly supported by an experiment of M. Gernez, in which he drew a large volume of country air through water, and then on evaporating it on a glass slide obtained crystals of sodium sulphate. I do not of course dispute his facts, but I have strong evidence to show that sodium sulphate is not generally present In a letter to "Nature" I described how drops of a very strong solution of the sulphate were placed on leaves, moss, wood, flowerpots, and many other substances in my garden near Bristol, and they quietly evaporated as the modified 7-atom salt—a considerable quantity of earth taken from the flower beds was inactive when dropped into the solution.

But it is not my garden only which is free from the sulphate; drops of this solution have remained liquid on the window sills in various rooms of the house. The following is a remarkable instance of what can be done with sodium sulphate, which is the most sensitive of all these solutions, and makes a fairly complete answer to M. Gernez.

I took a solution of the sulphate which had deposited abundance of the modified 7-atom salt, but this latter had dissolved again owing to the warmth of the weather. I cleaned a glass plate carefully and rubbed a little oil over a large surface, leaving it moderately thick at one side and then graduating in thinness till the other side was rubbed quite dry. Drops of the solution on the thick and thin films and on the unoiled parts all remained liquid; I rubbed one hard with my finger till quite dry; fresh drops on this surface remained liquid in every case. Repeated this on various parts of the plate. One of the drops crystallised spontaneously and two others while being rubbed, but the great majority remained liquid and evaporated, giving the 7-atom salt. These experiments were not made in my laboratory, because the air there would almost certainly have introduced something which would have caused crystallisation. I have done a great deal of work there with that salt, and it is quite possible that the dust contains some crystals. But to continue,—I then put some earth which had been exposed to the air in my laboratories for 9 hours into a good many of the drops, some of which were depositing the 7-atom salt at the time; always inactive; when these were nearly quite dry they were inactive to fresh drops of the solution. I then put some of the earth into the mother liquor in the test tube; left all these exposed to the air all night in my bedroom; next morning the drops were quite dry; at 11.30 I put fresh drops on the oily part, on the unoiled part, on the smears, on the earth and modified crystals; one drop out of four crystallised on the oil; none of the rest except two put purposely on the two smears, which had crystallised the night before; these crystallised instantly. The fresh drops on the plate gave the 7-atom salt, and also the amhydrous salt in octohedra by evaporation exposed to air. The day being cool the mother-liquor deposited the 7-atom salt on the earth. During the next two days similar results were obtained. The test tube with the solution was then carried into my laboratory at night; it remained liquid till next day, making three days that it had been

uncovered. In the afternoon it crystallised and set so firmly that on inverting the test tube not a single drop of liquid fell. I think that this experiment proves conclusively that air is not at all times full of sulphate of soda.

Next, with regard to other solutions than that of the sulphate, I find that sodium acetate is a most remarkable salt. It is extremely difficult to make a solution of this salt crystallise without introducing a crystal of the salt.* In a paper communicated to the Royal Society I described how I rubbed it in vain with dust on a bottle which had been standing for two years untouched in my laboratory, how I put it on the floor and all kinds of surfaces without causing crystallisation, and how drops remained supersaturated for two months on a plate exposed to air in my laboratory, and then crystallised on introducing a crystal. I have obtained similar results with Sodium Carbonate and with the Alums. Hence it is clear that these salts also are not generally present in the air or dust of my laboratory. I could describe experiments by the hundred, all proving the same point that air and dust are not storehouses of crystals of all kinds.

(2.) *The Adhesion Theory.*—In one of the experiments described above I laid stress on the fact that Sodium Sulphate remained liquid on films of oil, even when rubbed with them. Professor Tomlinson some years ago brought out the theory that crystallisation as the normal salt was caused by adhesion to a greasy or chemically unclean surface. The salt adheres to the surface while the liquid does not, and hence separation ensues. The main argument in its favour was that while a clean glass rod was inactive in these solutions, passing the rod through the fingers sufficed to make it immediately active. This is undoubtedly true—I explain the fact by supposing that in working with the salts and solutions the fingers take up some of the crystals which are then transferred

* A plate of drops was handed round for those present to try to make the drops crystalise ; it was returned with the drops liquid.

to the rod, and this is then active. I certainly find that when drops of the sulphate or other solutions are put in the palm of the hand before the solutions have been handled the drops can be rubbed hard with the fingers without causing crystallisation. Again, I have many times rubbed solutions of the acetate and carbonate with oil on a plate without producing any effect.

Some years ago when Mr. Tomlinson's theory was first brought out, I and other observers showed that drops of oil or tallow could be dropped into the solution and it prove inactive. Mr. Tomlinson replied that in this case as long as the oil floated as a lens no true adhesion took place between the oil and solution; but that if the flask were shaken so as to cause the oil to become a film, adhesion took place and separation of salt ensued. The effect was due to surface tension. He described a great number of experiments, in which shaking the flask in the manner described caused crystallisation. Without knowing the exact conditions of the experiment it is difficult to say what is the explanation of his results. Other observers have deposited films of all degrees of tenuity in the solutions; M. Gernez floated oil above one solution and pushed a glass rod through the oil into the solution. Mr. Tomlinson replied that the conditions of the experiment altered the surface tension. Hence the importance of the experiments described above in which sodium sulphate, acetate, and carbonate were rubbed with oil and greasy surfaces of all kinds without causing crystallisation. In the face of these experiments it seems to me impossible to assert that adhesion to a greasy surface is the general explanation of the crystallisation of these solutions. I do not mean to assert that oil has no effect on some solutions; a large quantity of oil throws down from the carbonate a modified salt which is quite inactive in the solution. Ammonia alum is very sensitive to oil, giving the normal salt. The fact of oil throwing down a modified carbonate is curious and needs working out.*

* Mr. Tomlinson has recently in a paper read before the Royal Society, called in question my results. At a meeting of the Physical and Chemical

(3.) *The Contact Theory.*—Jeannel stated that mere contact with a solid substance as a glass rod was sufficient to make these solutions crystallise. He gave sodium acetate as an example. The experiments described above with the acetate and other salts render it unnecessary to refer to this theory any further.

(4.) *Catalysis.*—This seems to be only a way of saying that the subject is inexplicable, and it need not detain us. We may have to fall back on it if all explanations fail, but we are not reduced to that yet.

(5.) *The Absorption Theory.*—Mr. Liversidge noticed that dry lycopodium powder is active in supersaturated solutions, while the same powder when wet is inactive. He suggested that it might absorb water and thus cause crystallisation. Mr. Tomlinson's nuclei would then be not little particles with a film of grease on them, but little absorbent particles. He did not, however, pursue the subject any further. I arrived independently at the same conclusion, and am able to give clear evidence that absorbent substances do cause crystallisation, provided that they are not at once saturated by the liquid, in which case no separation ensues. In the letter to "Nature" already referred to, I showed that I could make little mud pies of earth on the top of a flowerpot with the strongest solutions of sodium sulphate, and that earth from the flower beds could be dropped into the solution which deposited the 7-atom salt on the top of the earth; I found at the same time that drops of the solution put on the earth in the bed invariably crystallised at once. I could not explain the phenomenon at the time, and therefore did not mention it in my letter. I soon found that absorbent substances of all kinds act in just the same way, and on all kinds of solutions. I made an immense number of experiments and arrived at some interesting results, of which the following is a partial summary:—

section of the Bristol Naturalists' Society, held Feb. 26th, 1878, many of the above experiments, such as rubbing the sulphate on the palm of the hand, rubbing the acetate and carbonate, &c., were successfully shown.

(*a*.) Absorbent substances in large quantities are active to large drops, while the same absorbents in small quantities can be put into drops or into the solutions, and being saturated at once, are inactive. Many lumps of earth, large and small, were put on a glass plate and drops of sodium carbonate put on each; all the small lumps were inactive; all the large but one were active. Earth which had been in an open box in my laboratory for two years was pounded and put into many drops of the sulphate and was inactive; the drops put on the earth crystallised. Swedish filter paper was cut into small pieces and was put into flasks, test tubes, and drops of the carbonate, sulphate, and acetate, and was inactive; drops of the solutions on the same filter paper crystallised as the normal salt. Plaster of Paris was inactive in small quantities in various solutions, and often active in large quantities. A supersaturated solution of sodium sulphate in sulphuric acid can be rubbed on a glass plate with bone, or hard close grained wood, but the end of a match makes it crystallise even without rubbing; small shavings of wood when at once saturated by being pushed into drops of this solution were inactive; when left floating or when larger in size they were active.

(*b*.) The same absorbents produce different results in different solutions. Small bits of filter paper are almost invariably inactive in the sulphate carbonate and acetate, but are active in strong potash alum. In the experiments described above the sodium sulphate may be either weak or strong, it will always crystallise on filter paper; the carbonate must be strong; drops of weaker solutions are absorbed entirely and evaporate as the 7-atom modified salt, or if of moderate strength they often give the modified salt at once. Swedish filter paper gives the normal carbonate much more readily than thin blotting paper does. Filter paper acts only on the strongest solutions of the acetate. The slightly absorbent action of thin straw paper makes drops of the sulphate often evaporate as the anhydrous instead of the 7-atom salt which it gives on glass. Ammonia alum is exceedingly sensitive to absorbents,

blotting paper makes it give the normal salt at once—but a drop on some thin blotting paper which had been scraped with a knife was absorbed.

(*c*.) Rapid absorption often prevents crystallisation. There seems to be no time for the crystals to form. If the carbonate be melted in a test-tube and allowed to cool, a very strong solution is obtained. Small drops of this can be put in a circle round the edge of a sheet of filter paper and will all be absorbed; but if two or three large drops are put on the paper together they will crystallise as the normal.* Strong solutions of the same which give the normal generally on lumps of dry earth are frequently absorbed by pounded earth, because the absorption is more rapid. A cake of plaster of Paris was repeatedly active, while the same cake pounded was inactive. The scraped blotting paper mentioned above was probably inactive to ammonia alum because the rough surface promoted rapid absorption.

How absorbents act. It seems probable that these absorbents act by abstracting water, and that therefore their action is analogous to that of evaporation. The abstraction of water in the Carbonate takes place in regular steps, depending on the amount of water present, but always modified by the tendency of rapid absorption to prevent crystallisation. Thus a slow rate of absorption as of large drops of very strong solutions gives the normal salt, both on filter paper and earth. Solutions of medium strength give salts with less water on paper and earth. Weak solutions are entirely absorbed and only give the modified salts by slow evaporation.

It is worth noticing that the chemical affinity for water of the Acetate, Carbonate, and Sulphate of soda, agrees exactly with their behaviour to absorbents. The acetate has the strongest affinity for water; the drysalt does not effloresce except in very dry air, and then only very slightly; the anhydrous salt is very deliquescent,

* This experiment, with others, was repeated at the meeting of the Chemical Section mentioned, (1878.)

and the solutions absorb water from the air greedily.—If a drop of a strong solution is put on blotting paper, and then this warmed over a flame so as to make the salt anhydrous and is then hung up, a dark spot shows itself in about ten minutes, which dries up instantly it is touched with a crystal. Drops of strong solutions on glass rapidly increase in size, but I do not think that they ever absorb water beyond the limit of supersaturation. When a crystal is introduced, it takes some time—a couple of hours perhaps, or more—before the crystal is seen to have increased much in size. They might, perhaps, do so in very wet weather. This strong affinity for water seems to be the reason why absorbents have so little effect on the solutions, only acting on the very strongest ones.

The Carbonate stands next in order: the drysalt effloresces, but not at all readily, unless the air is very dry; the solutions on glass slowly evaporate, giving the modified salts: boiling the solution does not separate any anhydrous salt, only a monohydrate. Hence absorbents act much more readily on these solutions than on the acetate, giving the normal salt in strong solutions and the modified salts in weaker ones, while still weaker ones are not affected at all.

The sulphate both in the dry state and in solution is very easily rendered anhydrous. It effloresces quickly, and boiling gives abundance of anhydrous salt. Hence absorbents act very readily on it, and it always crystallises on blotting paper however weak the solution is.

Aerial Nuclei.—The fact that absorbent substances cause crystallisation having been thus established, it is evident that a considerable amount of light is thrown on the sensitiveness of these solutions, and especially of sodium sulphate. Aerial nuclei may now in many cases be supposed to be light absorbent particles. These have no effect on the acetate at all, and I never cover solutions of this salt however strong. They would act only on strong solutions of the carbonate, and as a matter of fact, I never cover solutions unless they contain three or more parts of salt to one of water.

The sulphate is much the most sensitive, and specks of soot have often been seen to cause crystallisation: it is advisable to keep the sulphate covered in rooms, especially in cold weather. I imagine that these nuclei settle very lightly on the surface and therefore are not at once saturated, but are able to act by absorption, The temperature also affects the results: at a low temperature an absorbent may be active which is inactive at a higher one, because then the tendency of the salt to separate out is less.

Adhesion of Crystals.—The apparent sensitiveness of these solutions can in some cases be explained by the remarkable power of adhesion, exhibited by the salts to any surface on which they have been allowed to crystallise: the minutest trace of a crystal is sufficient to make a drop crystallise when brought in actual contact.—I was much puzzled once by a glass plate which had been used for the acetate, and then washed carefully in cold water.—Drops of the solution remained liquid on all parts of the plate, but if a drop was scratched with a sharp point it crystallised instantly. At first I attributed the effect to the scratching, but I found, at last, that on washing the plate in hot water scratching produced no effect at all.—The drops remained liquid, because the crystals were adhering in the depression of the rough glass, and were covered with a layer of water. So a pin which has been heated red hot several times gets a rough surface on which the acetate may be allowed to crystallise. It often then becomes almost impossible to clean the pin in cold water. It can be laid in a drop and produce no immediate effect, but is instantly active on scratching the plate. I left a pin for three and a half hours in water and it was then active on scratching. When a pin thus washed is left in a drop of the solution a curious effect is often produced. When a crystal is introduced, the drop, as a rule, crystallises with a sort of flash, the whole becoming solid at once; but in the case of these washed pins no immediate effect is seen, but on standing for an hour or two, well marked, large, distinct crystals are formed, which grow very slowly, being constantly surrounded by an impoverished layer of the solution.

Sodium Carbonate adheres to a pin in the same sort of way, but the sulphate is very readily got rid of by cold water.

Effect of Scratching.—In a paper communicated to the Royal Society, I described how a solution of sodium sulphate in about six parts of sulphuric acid, can be made to crystallize by scratching on a hard surface. On finding the remarkable adhesiveness of the acetate mentioned above, I thought, perhaps, my plates were not quite clear, especially as I had already found that a scratch on copper which had been active in one drop, proved active at once to a fresh drop, although it had been washed and scrubbed with a brush. I therefore tried all kinds of ways of cleaning the plates; boiling them with ammonia and barium chloride and drying them over calcium chloride. Yet on removing the plate from the calcium chloride in the open air, and putting drops on the plates, I found that a glass rod, which had also been boiled with barium chloride, was invariably active on scratching. In my previous paper I had attributed the result to vibration upsetting the state of unstable equilibrium in which these solutions exist. I am not sure that it is not simply a case of absorption. I have already described how shavings of wood were active in this solution; it seems possible that small particles of organic matter adhering to the dry plate and there set up crystallization in the depressions of the plate. As in the case of the boiled pins these might grow very slowly, while scratching brings them in contact with the mass of the solution and sudden crystallization follows.

Remarkable Fossil Deposits near Bristol.

No. 1.—SINGULAR DEPOSIT OF THE FOSSIL BONES OF THE WATER VOLE (ARVICOLA AMPHIBIA.)

BY W. W. STODDART, F.G.S., F.C.S.

DURING an excursion made a short time since, the members of the geological section went to examine a very remarkable quarry of carboniferous limestone, about 6 miles S. W. of Frome, near the little village of Hollwell. It is the same locality so famous for the discovery of Rhætic remains by C. Moore, Esq., of Bath, and it is through the kindness of that gentleman that my attention was first called to the deposit of bones now under our notice.

The Quarry, like many in the neighbourhood, is very remarkable for what Mr. Moore very appropriately calls "Abnormal deposits." The carboniferous limestone is here divided by several metalliferous dykes, and fissures filled up with bones of much later times.

One of these crevices has been described by Mr. Moore in the Journal of the Geological Society as containing many thousands

of the teeth of a Rhætic fish (Lophodus) very similar to those found so abundantly at Aust Cliff, in the well-known bone bed. A few yards to the west of this crevice is another also filled with loam literally packed with the bones of rodent animals which on examination turn out to be those of the Arvicola, or Water Vole—in this part of the kingdom commonly though erroneously called the Water Rat. Other bones of amphibious animals also occur, but those of Arvicola largely predominate. A geological examination of the locality and the northern part of Somerset will I think show that in former times it was a well watered country, abounding in streams and lakes, the banks of which were inhabited by Water Voles and other animals similar in their habits to the Beaver. The fissure or crevice in question was probably the site of an old stream and now filled up by mud and some rock, but not by drift as some suppose. My reasons for thus thinking are: 1st.—That the deposit is a fine mud without any small stones or gravel, as in the drift near Cheddar, Draycott, Sandford, and Axbridge. 2ndly.—That the nature of the loam agrees with the neighbouring rocks, and is very similar to the loam found in the contiguous crevice, which contains the Rhætic fossils, both in colour and physical character. 3rdly.—That with the bones also occur the excrement of the Arvicola, which would differ much in the specific gravity and would not be likely to be found with the bones if subjected to the action of running water. 4thly.—That with the fossil bones are also small but perfect crystals of calcite with the angles quite sharply defined and not in the least water worn. 5thly.—That the loam is exactly similar to that found in the caves at Cheddar, Lexton, &c., and which are closed cavities. So plentiful are the bones in the deposit that many hundreds may be collected in a few minutes. Some of the most perfect and plentiful are drawn in the accompanying lithograph.

Indeed the prevalence of the Water Vole in Post Tertiary strata is so great that immense numbers of these curious mammals must have existed at that period. Mr. R. Pennington in his notes on the

barrows and caves of Derbyshire says, "I never explored either a burial mound or a cave without finding plenty of the remains of the Water Vole. Indeed they come out by spadefuls."

Although the Water Vole is often called the Water Rat, it is not a true rat at all, but is more nearly related to the Beaver, both in its anatomy and habits.

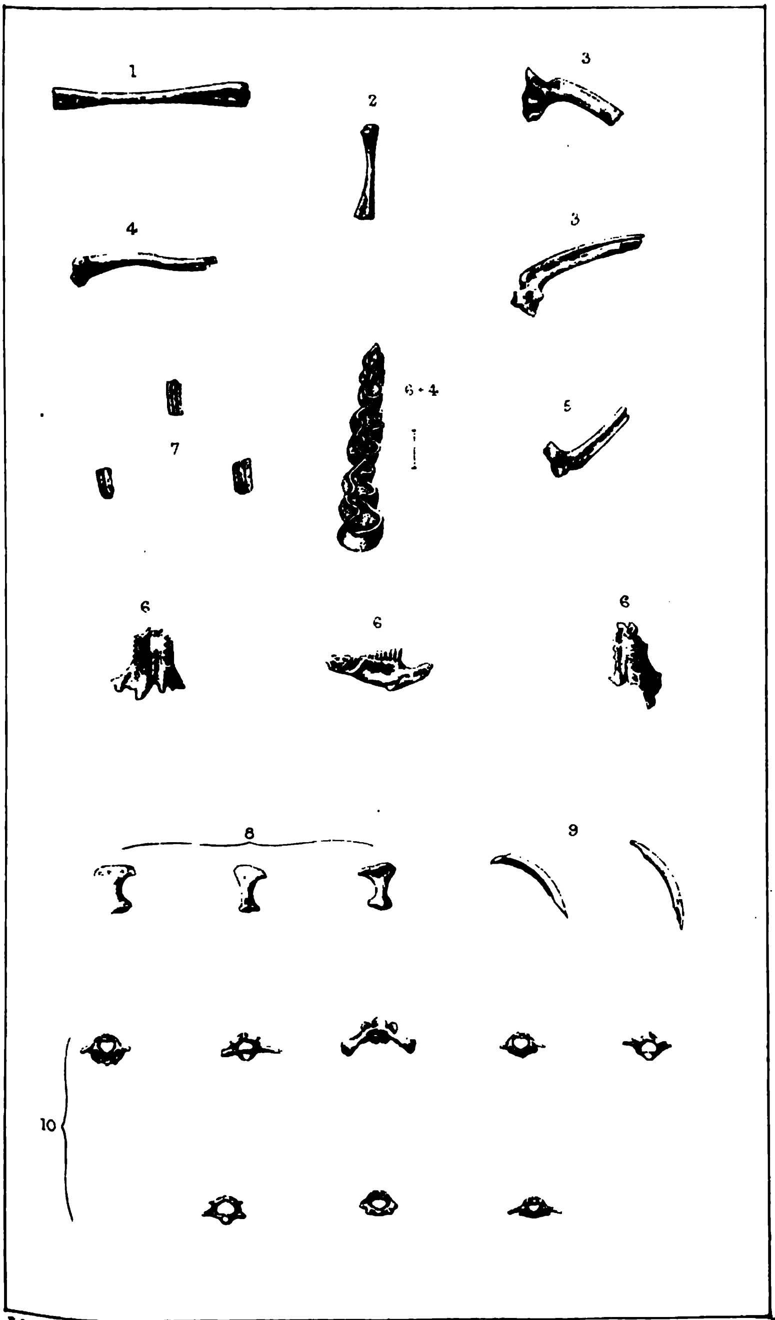
The Beaver (*Castor fiber*) has five toes on each foot, those of the hinder feet webbed and has the tail flattened horizontally. It is a true vegetable feeder, and in winter lives in an underground habitation, nicely lined and very clean.

The Vole (*Arvicola amphibia*) has five toes on the hinder feet, but the fore feet have only four complete ones with a rudimentary fifth or thumb. The teeth differ very materially from those of the beaver and the rat.

The curious incisor teeth deserve special attention. They are covered with hard enamel on the convex side, so that as the bone wears down much faster than the enamel, the extremity of the teeth maintain a sharp cutting edge. The great length of the incisors is remarkable in all the rodentia. Their shape resemble the segment of a circle. The extremities of the fossil incisors closely resemble those of the beaver, and are more chisel shaped than those of the rat. Linnæus was so struck with the habits of the Arvicola and its affinity to the Beaver that in his "Fauna suecica" he gave it the generic name of Castor.

The Arvicola, like the Beaver, is a true vegetable feeder, is scrupulously clean in its habits, and like the Beaver inhabits the banks of streams and lakes. It has often been accused of being destructive to fish, but this is a popular mistake, for on the contrary, it is often devoured by Pike and Trout. In short the Arvicola may be fairly taken as the English successor to the Beaver, which in Britain has died out and quite disappeared.

On the other hand the Rat (*Mus decumanus*) is well distinguished from the Vole by being a true flesh eater, and is not very particular in the quality of the flesh with which it meets, or in the cleanliness



E.C. Lavars. J. Lavars, lith. Bristol.

of its habitation. The error of confounding the Arvicola with the Rat doubtlessly arises from similarity in external appearance, and that the Rat, when occasion requires, is a bold swimmer.

With the other fossils I found a single tooth of a mammal, the name of which I have not yet been able to determine, but is that of a mammal which has no resemblance to the tooth of an Arvicola.

Rainfall at Clifton in 1877.

By GEORGE F. BURDER, M.D., F.M.S.

TABLE OF RAINFALL.

	1877.	Average of 25 years.	Departure from Average.	Greatest Fall in 24 hours.		Number of days on which 0.1 in. or more fell.
				Depth.	Date.	
	Inches.	Inches.	Inches.	Inches.		
January ...	4.699	3.462	+1.137	0.705	3rd	27
February ...	2.376	2.120	+0.256	0.370	19th	17
March	2.451	2.247	+0.204	0.568	28th	18
April.........	2.977	2.057	+0.920	0.435	4th	15
May	2.213	2.284	—0.071	0.672	16th	12
June	1.182	2.441	—1.259	0.357	1st	8
July	3.136	2.783	+0.353	0.791	14th	16
August	5.186	3.404	+1.782	0.815	27th	16
September ..	2.873	3.414	—0.541	0.780	2nd	7
October......	3.103	3.646	—0.543	0.663	28th	15
November...	5.932	2.749	+3.183	0.934	24th	22
December...	2.202	2.711	—0.509	0.495	28th	15
Year	38.230	33.319	+4.911	0.934	Nov.24th	188

REMARKS.—The year 1877 was the fourth consecutive year of excessive rainfall. The period from 1872 to 1877 comprises the three wettest years that have occurred in a quarter of a century. A comparative view of the rainfall of these six years is given in the following table.

RAINFALL OF SIX YEARS.

Year.	Rainfall.	Departure from average of 25 years.
	Inches.	Inches.
1872	42.366	+ 9.047
1873	32.069	— 1.250
1874	35.248	+ 1.929
1875	44.047	+10.728
1876	42.415	+ 9.096
1877	38.230	+ 4.911
Mean of 6 years.	39.062	+5.743

It will be observed that the average annual rainfall of the last six years has been over 39 inches, and the average annual excess during this period, nearly 5¾ inches. These results are noteworthy, both as showing how little dependence can be placed upon short averages, and also as pointing to the probability of deficient rainfall in coming years. It may further be remarked, that the excessive rainfall of recent years is singularly at variance with the theory now so popular among meteorologists, according to which years of many sun-spots are years of much rain, and years of few sun-spots are years of little rain.

The wettest month in 1877 was November, with nearly six inches; the driest was June, with something over an inch.

The heaviest diurnal fall, 0.934 inch, occurred on the 24th of November.

The number of days per month on which rain fell to the amount of a hundredth of an inch or more, ranged from seven in September to twenty-seven in January. On the whole year rain fell, on an average, somewhat oftener than every second day.

There was no measurable depth of snow throughout the year.

The column in the first table, which gives the average rainfall of each month and of the year, may claim to have something

more than a passing interest. The observations upon which thes averages are founded, have been continued without a break fo twenty-five years—a period which may be considered long enoug to ensure trustworthy results.

The average rainfall for the whole year at Clifton, as deduce from these twenty-five years' observations, is 33.319 inches. Th monthly averages differ widely. From April, the driest montl with 2.057 inches, the quantity increases month by month unt October, the wettest month, with 3.646 inches. Betwee October and April the fluctuations are irregular. Februar March, April and May are all dry months. August, Septembe and October are relatively wet months.

The aggregate depth of rain in the 25 years has been littl short of 70 feet.

Catalogue of the Lepidoptera of the Bristol District.

PART 1.

BY ALFRED E. HUDD, M.E.S.

Read before the Entomological Section.

THIS contribution towards the Natural History of the Bristol District so long projected by our Society, was commenced more than ten years since, by Mr. Harding and myself. Our original intention was to have restricted the list to recording only those species of Lepidoptera which we had ourselves met with, or knew to have been captured, within a nine mile radius of Bristol; but after making considerable progress with this list it was discontinued, and has remained in an incomplete state ever since.

In the catalogue of which the first portion is now published, I have considerably enlarged the area of my district, which now includes the whole of the "Bristol Coalfield" as given in Mr. Sander's well known map.

The neighbourhood of Bristol is undoubtedly very rich in the number of *species* of Lepidoptera, as a glance at the list will show;

but very many of the species recorded have only been met once or twice, and hardly any of the "good things" are found in abundance, so that collecting, even in our successful hunting grounds, is generally most disappointi entomologists used to some other parts of England. I pos further remarks on this subject till the conclusion of my catal

I have received considerable assistance in my work from m the entomologists resident in the district, to all of whom I beg to offer my warmest thanks. In many cases I have myself the specimens of the rare insects recorded from the neighbour and have excluded a few species of the claims of which I di feel quite satisfied. As my friend Mr. C. G. Barrett says, excellent "List of Norfolk Lepidoptera," (which I have tak my model), "it is better to exclude a few species than tc including any which do not belong to the district!!" I adopted his plan of giving doubtful species, and also localitie beyond my limits, in brackets [ ], when I thought remarks them might be of interest.

Of the Bristol Entomologists to whom I am indebted, I first mention the name of our Honorary Secretary, Mr. G Harding, without whose assistance I should never have under the work: his information has been most valuable and exte I have also to thank Messrs. S. Barton, I. W. Clarke, R. Fi W. H. Grigg, E. Spencer, Pease, P. H. Vaughan, the Re Greene and G. W. Braikenridge, and others, for records c capture of rare or interesting species near Bristol. Mr. J. G. has kindly sent me a list of captures near Bath, and Dr.] Livett of species found at and near Wells. To Mr. V. R. P I am indebted for a list of species taken by himself in the imm neighbourhood of Wotton-under-Edge, during about thirty residence there; and also to the Rev. W. Farren White, and M G. Musgrave, for interesting captures in the Stroud di Though Stroud itself is rather beyond my limits, part c immediate neighbourhood is included in my district.

I have in my list given the initials of the above named entomologists after the localities named by them.

I have obtained much information respecting the insect productions of the vicinity of Almondsbury, from a diary kept, during his residence in that locality, by Mr. J. Allen Hill, (for the loan of which I have to thank Mr. Harding).

Mr. H. Jenner Fust, Junior, of Hill, kindly sent me a long list of references to books and periodicals, in which species from my district had been recorded, and also a list of 425 species of Lepidoptera taken near Weston-super-Mare, by the late Mr. G. R. Crotch, during his residence at Uphill.

The following are among the publications I have availed myself of, most of which I have consulted, but in a few cases have quoted on the authority of Mr. Jenner Fust.—

Samouelle's—"Entomologist's Useful Compendium," (1824.)

"Magazine of Natural History," several early vols., (1831, &c.)

Morris & Bree's—"Naturalist," (1854, &c.)

Newman's—"Zoologist" and "Entomologist," various vols., and "British Butterflies."

Stainton's—"Manual," "Intelligencer," and "Annuals."

Duck's—"Natural History of Portishead."—(J.N.D.)

"The Entomologist's Monthly Magazine."—(E.M.M.)

&c. &c.

Lepidoptera of the Bristol District.

Diurni.

Papilio Machaon, L. Reported from the neighbourhoc Bristol, in Samouelle's *Entomologist's* i *Compendium*, p. 235, "It is very local, occurs near Bristol," &c. A friend tells on what he calls "only schoolboy autho that *P. Machaon*, used to be found ir marshes near Aust, Gloucestershire. I been unable to obtain any further inform on this point, and have no doubt the sp has long since disappeared from our n bourhood, as it has from most of it localities in other parts of England.

Leucophasia sinapis. L. Not common in the district, very local.

Glos. It has been taken near Stapl p.h.v. Scarce in Alderly Down Woods. \ Mr. H. Phillips and Mr. A. Nash used tc *Sinapis* rather freely in woods near Du g h. Mr. H. W. Marsden took one spec at Dursley, 1868.

Somerset. The Rev. G. W. Braiken reports the capture of single specimens Clevedon, and Tickenham, many years ag is marked on Mr. Crotch's list of species 1 near Weston-super-Mare

[Also recorded from woods near Taunton, by Mr. Rawlinson, *Intelligencer*, Vol. I., p. 5; and by Mr. Stansell, *Entomologist*, Vol. VIII. p. 158.]

PIERIS CRATÆGI. L. Has apparently become very scarce in the West of England, not having been noticed lately in many of its old localities.

" " GLOS. Boiling Wells, Bristol. Scarce. S.B. Used to occur near Stroud. M.G.M.
SOMERSET. Filwood. F. V. Jacques. Rare at Portishead. J.N.D. Clevedon. A.E.H. Worle. G.H. Weston-s.-m. G.R.C.

" BRASSICÆ. L. Common throughout the district. "In 1872, I took a specimen on March 30th, at Wotton, and that year it was unusually abundant; in the autumn of 1877, it was also in prodigious numbers." V. R. Perkins, *in litt.*

" RAPÆ. L. Abundant everywhere. The earliest and latest dates of its first appearance, from 1864 to 1877 (as recorded by Mr. Perkins) are "March 16th, 1874," and "April 24th, 1866."

" NAPI. L. Throughout the district, appearing rather later than *P. rapæ*, and not quite so abundantly.

" DAPLIDICE. L. GLOS. A specimen of the "Bath White" was captured many years ago, near the Bristol Royal Infirmary, by Dr. Dyer. Mr. H. C. Harford. (*Communicated by Mr. Harding.*)
SOMERSET. A specimen taken near Bath, is recorded by Lewin, *Magazine of Natural History for* 1831. "One captured by J. S. M. in a field near Keynsham, in 1818, was in the cabinet of Mr. Miller, of Bristol." Dale, in *Mag. Nat. Hist. for* 1831. Mr. Barton informs me, this last named specimen used to be

in the collection of the Bristol Museum, and I have discovered lately an old specimen of *Daplidice*, (which I believe to be the one referred to), among the *Exotic* species in the cabinet there.

[Mr. Thomas Lighton of Clifton, reports the capture of a specimen of *Daplidice*, in Roseberry Wood, near Exeter, *Zoologist, Oct.*, 1843.]

ANTHOCHARIS CARDAMINES. L. Rather local, but common in lanes, &c., throughout the district. Mr. Perkins says, "first appears, from April 12th to 27th, at Wotton; I have taken some remarkably small specimens of both sexes." *In litt.*

GONEPTERYX RHAMNI. L. Common throughout the district.

COLIAS EDUSA. Fab. Throughout the district; occasionally common; very plentiful in 1877.

,, ,, Var. HELICE, Hüb. Not recorded from Gloucestershire.

SOMERSET. Mr. Smith, of Sundon House, has a beautiful specimen in his collection, which was captured at Burnham, in August, 1876. Near Weston-s.-m. G.R.C.

,, HYALE. L. GLOS. Used to be taken I think, by Mr. Mayes; I once saw a specimen in my garden at Redland, which I believe was this species but not having captured it, may have been deceived by *Helice*. P.H.V. Bristol. Stainton's "Manual."

SOMERSET. One specimen taken near Bristol many years ago, by Mr. Barton. [The only other record I have been able to obtain of *Hyale* in Somerset, is in the *Entomologist, VII.*, p. 159. "In 1865, *C. Edusa* swarmed at Orchard Wood, near Taunton, and *C. Hyale* occurred singly."—*F. Stansell.*]

ARGYNNIS PAPHIA. L. Local and not very common in the district.

GLOS. One specimen was caught on Redland Green, in 1867, by Mr. I. W. Clarke. Wotton-under-Edge. V.R.P. Near Stroud. W.F.W.

SOMERSET. Tolerably common in woods at Brockley and Weston-super-Mare; scarce in Leigh Woods and near Brislington. Wells. Dr. Livett.

„ AGLAIA. L. GLOS. Durdham Down, not common. P.H.V. Occurs in most of the hill districts about Wotton-under-Edge. V.R.P. Dursley. J. Merrin. Westbury. Mr. Pease.

SOMERSET. Brockley, rather common, Clevedon and Portishead. A.E.H. Weston-super-Mare. G.R.C. Local.

„ ADIPPE. F. GLOS. Coombe Glen, Bristol. F. D. Wheeler. Wotton-under-Edge. V.R.P. Near Stroud. M.G M.

SOMERSET. Portishead. J.N.D. Brockley. J.W.C. Clevedon. A.E.H. Weston-super-Mare. G.R.C. Local.

„ LATHONIA. L. GLOS. A specimen was taken many years ago, in Garaway's Nursery Grounds, Clifton. P.H.V. Bristol. Stainton's "*Manual*," Vol. I, p. 43.

SOMERSET. Mr. Harding tells me a specimen was shown to Mr. Arthur Naish, which was captured near Nailsea, about twenty years ago. [In the *Zoologist*, for Oct., 1843, Mr. T. Lighton records the capture of a specimen in Roseberry Wood, near Exeter, in 1836.]

„ EUPHROSYNE. L. Generally distributed throughout the district, but not so common near Bristol as

formerly, This is one of the victims of makers of "butterfly pictures," who used to capture them by hundreds at Leigh, and other localities where they are not now often seen in any numbers.

,, SELENE. F. Occurs in the same localities as the last-named species, but is rather more local, and appears about ten days later in the season.

MELITÆA ARTEMIS. F. GLOS. Boiling Wells, Bristol. G.H. Old Market Street, Bristol, and Durdham Down. A.E.H. Almondsbury. J.A.H. Alderley lower Woods, Wotton-under-Edge. V.R.P. Near Dursley. W.F.W.

SOMERSET. Portishead, J.N.D. Hallatrow. R. V. Sherring. Weston-super-Mare. G.R.C. Wells. Dr. Livett. Local, but not scarce in marshy meadows.

VANESSA C. ALBUM. L. This species, though nowhere very common, seems to be generally distributed throughout the district. It is not, however, marked on Dr. Livett's list from Wells. Mr. Perkins says of this species—" A great lover of wall fruit, apricots, plums, &c. It sometimes occurs at Wotton-under-Edge in profusion, and varies greatly both in form and colour."—.V.R.P *in litt.*

,, URTICAE. L. Abundant everywhere.

,, POLYCHLOROS. L. Generally distributed throughout the district, but rather local. Mr. Vaughan says, " common some years in all its stages." " In great abundance at Wotton-under-Edge, in 1859; is fond of hybernating indoors." V.R.P.

,, ANTIOPA. L. Several specimens of this beautiful rarity have been recorded from the district.

GLOS. Mr. Robert Mayes has one in his collection, which was captured by his father, near Durdham Down, more than twenty years since. A specimen was taken near the Gully, Durdham Down, in August, 1872, by Mr. Clark. "My friend, Mr. Hill, saw a fine specimen of *V. Antiopa* near the Berkeley Road Station, on August 5th, 1875, but did not succeed in capturing it." J. Preston, in "Entomologist," VIII. *p.* 220. "One was seen by Mrs. Harding, at Downend, in August, 1877." G.H.

"*V. Antiopa* has been *seen* in the Stroud Cemetery (in 1872) by the former keeper, an accurate observer." W.F.W.

[It has also been recorded from Newnham and Cheltenham, which are, however, outside my district.]

SOMERSET. "Goblin Coombe, near Bristol." James Francis Stephens, in the "Zoologist," Vol. III., p. 945. His account is so good, I give it *verbatim*. "While entomologising in Goblin Coombe, a romantic glen near Cleeve, Somerset, in August last (1844), a fine specimen of this beautiful insect settled on a rock before me, and 'ere I could secure it, took flight and ascended a lofty precipice; in a few moments it re-appeared almost in the original spot, but again took flight down the precipice, and finally eluded my grasp, to my great mortification."

A specimen was taken near the Bourton Railway Station (G.W. Rail.), about August, 1866. Dr. Livett tells me—"Two were seen, one captured on the Mendips, near Wells, in August, 1872." Mr. Crotch recorded one from near

Taunton, and two or more have been taken near Bridgewater, one of which, captured in 1870, is in the Clifton College collection.

VANESSA IO. L. Common everywhere.

„ ATALANTA. L. „ „

„ CARDUI. L. Generally common, in some years abundant, but always rather local.

LIMENITIS SIBYLLA. L. GLOS. The only specimen which has (so far as I know), been recorded from the county, was captured by Mr. Crawford, on the bank of the Avon below Cook's Folly, more than twenty years ago. Mr. Harding tells me he saw the specimen a few days after its capture, and has no doubt of its having been taken in the locality named.

SOMERSET. I have heard, on *doubtful* authority, that several specimens of the "White Admiral" were taken in Brockley Wood, by a local collector, many years since, but have failed in verifying the statement. *A. Iris* was also said to have been taken there by the same collector.

APATURA IRIS L. GLOS. [No records in my district, but it occurs in the Forest of Dean, and on the banks of the Wye].

SOMERSET. Woods near Winscombe. T.H.O.P. Several specimens have been reported as seen on the wing in Brockley Woods, but I know of no captures there. The last reported was by Mr. Last, in 1870. As the "Purple Emperor" is notoriously much more easily seen than captured, and could not well be mistaken for any other British butterfly, I feel no doubt the species does occur at Brockley.

Arge Galatea. L. Glos. Stapleton and Purdown, scarce. G.H. Common on all the hills about Wotton-under-Edge. V.R.P. Dursley. A.E.H. "Universally common on rough, waste land in the Stroud district."—M.G.M. &c.

Somerset. This pretty species used to be common in fields near Bedminster, but is now seldom met with in the neighbourhood of Bristol. Portishead and Clevedon, F. D. Wheeler. Weston-s.-m. G.R.C. Brean Down. T.H.O.P.

Satyrus Ægeria. L. Rather local, but abundant in many woods and lanes throughout the district, especially near Weston-s.-m.

" **Megæra.** L. Generally distributed, but not everywhere common.

" **Semele.** L. Abundant throughout both counties, on limestone hills and downs.

" **Janira.** L. Abundant everywhere.

" **Tithonus.** L. Do. do.

" **Hyperanthus.** L. Rather local, in woods, but common where it occurs. Ringless varieties are not uncommon at Brockley Coombe.

Chortobius Pamphilus. L. Abundant everywhere, on heaths and downs.

Thecla rubi. L. Generally distributed, and sometimes plentiful on blossoms of bramble, nettle, wild medlar, &c.

" **quercus.** L. Generally distributed and common in oak woods. Larvæ plentiful at Leigh.

" **w-album.** Illig. Glos. "Used to occur on Durdham Down." S. Barton. One at Westbury in 1876, T.H.O.P. One at Hill, near Berkeley, in 1867. H J.P. Larvæ common at Coombe

Dingle, near Bristol, in 1869. F.D.W.

SOMERSET. Brockley Coombe. A.E.H. Weston-s.-m. G.R.C. Local and scarce.

THECLA [PRUNI. L.] Not recorded from my district, but Mr. F. D. Wheeler tells me it has been taken in the Forest of Dean, a fact which has not, I think, been hitherto published.

„ BETULÆ. L. GLOS. "Occurs near Gloucester, but scarce."—J Merrin, in Newman's *Butterflies*, p. 113. This locality is probably rather beyond the limit of my district. The species has also been taken near Monmouth.

SOMERSET. An old schoolfellow, Mr. F. Harvey, informed me many years since that he had captured a specimen of the "brown hair-streak," near Brockley Coombe. In reply to a letter I wrote him on the subject, Mr. Eustace Button of Clevedon writes me—"In the school 'Manual,' where captures are recorded, I find entered '*T. Betulæ caught at Yatton*, 1861.' I think you would be safe to include it in your list, as I feel sure it has occurred in the neighbourhood." [It has also been recorded from "near Taunton."]

POLYOMMATUS PHLÆAS. L. Common, and generally distributed.

LYCÆNA ÆGON. Bork. GLOS. Durdham Down, and Stapleton, scarce. G.H.

SOMERSET. Weston-s.-m. E.S. and G.R.C. Very local, and scarce.

„ AGESTIS. W. V. Throughout the district, common, but rather local. Some curious varieties have been taken.

„ ALEXIS. W. V. Abundant everywhere. The "small variety scarcely larger than *L. Alsus*," recorded

from Wotton-under-edge by Mr. Perkins, has also been taken on Durdham Down, late in the autumn. It may be a third brood.

LYCÆNA ADONIS. W. V. GLOS. Clifton, Durdham, and Coombe Downs, and Henbury. A.E.H. Stapleton. G.H. Wotton-u.-e. V.R.P. Local, but sometimes common.

SOMERSET. Not recorded from this county, though it probably occurs on the downs south of the Avon.

„ CORYDON. F. GLOS. This species seems to be found throughout the county on limestone hills and downs, though it has of late nearly disappeared from some of its old localities. Stapleton, Durdham and Coombe Downs, Bristol, Wotton-under-Edge, Dursley, Rodborough, &c.

SOMERSET. Leigh Down, scarce, Brean Down and Weston-super-Mare. A.E.H. G.R.C.

„ ACIS. W.V. GLOS. "Two specimens, taken at Stinchcombe and Break-Heart Hill, near Wotton-under-Edge, are in Mr. Cooper's collection."—V.R.P. Mr. Perkins tells me this scarce species "used to occur, not unfrequently, near Wotton-under-Edge, but the last captures heard of were in 1858. I searched for it in all its old haunts last season, but without success." *In. litt.*, March, 1878.

A single specimen was taken near Dursley, by Mr. Evan John, in June 1865, which is now in Mr. Harding's cabinet. [The Rev. Jos. Greene took two specimens on the Cotswolds, N. of my district, in 1849].

SOMERSET. "I took two or three flying in a pasture field at the bottom of the hill, near Bath;

they were much wasted in colour, and appeared to have been long on the wing."—Lewin, quoted in Newman's "*Butterflies*," *p*. 133. Near Bath. G.R.C. Mr. Grigg has a male specimen said to have been taken on Leigh Down, about ten years ago, by a Bristol collector.

LYCÆNA ALSUS. F. GLOS. Durdham Down, scarce. A.E.H. Worcombe Fir plantation, common, but local. J.A.H. Wotton-under-Edge. V.R.P. Rodborough Common. M.G.M.

SOMERSET. Clevedon, Portishead, Brockley, Wookey, Wells, Weston-super-Mare, &c. Very local, but generally common where it occurs.

„ ARGIOLUS. L. Common amongst holly and ivy throughout the district. "It seems not so generally known as it should be, that the spring brood feeds up in the autumn, and passes the winter in pupa."—F. D. Wheeler: *in. litt.*

„ ARION. L. GLOS. "Near Wotton-under-Edge; it has not turned up in the parish, but within a very short distance." V.R.P. Rodborough Common and other localities near Stroud. M.G.M. Stinchcombe Hill, near Dursley.

SOMERSET. "Hills near Bath."—Lewin, quoted in Newman's "*Butterflies*," *p*. 140. The late Mr. Queckett of Langport, used to take this species in considerable numbers, "in a field abounding with long grass and brambles, near Langport," having captured upwards of sixty specimens on two days, (June 15th, 1833, and June 15th, 1834). The late Mr. Dale also took this species in the same locality. See "*Entomological Magazine*," *Vol. II.*, *and* Newman's "*Butterflies*," *p*. 140.

L. Arion is marked on Mr. Crotch's list from Weston, but without locality. It would be well worth while to endeavour to re-discover the Somersetshire quarters of this lovely butterfly.

NEMEOBIUS LUCINA. L. GLOS. Conygre Wood. J.A.H. Woods round Wotton-under-Edge. V.R.P. Dursley. E.J. Near Woodchester. P.H.V.
SOMERSET. Warleigh Wood, near Bath. G.W.B. Orchard Wood, near Taunton. Local, but abundant in most of the places named.

SYRICTHUS ALVEOLUS. Hüb. Generally distributed, and common. The variety *malvæ* occurs at Leigh.

THANAOS TAGES. L. Common throughout the district.

HESPERIA SYLVANUS. Esp. Generally distributed, and common.

„ COMMA. L. GLOS. "Rodborough Common: used to be very scarce, but has become plentiful of late." M.G.M.
SOMERSET. "Among insects from Weston, and taken there, I think." P.H.V. Mr. Robt. Last is reported to have taken several specimens at Brockley in 1872. [Rare near Exeter]. Mr. Parfitt.

„ LINEA. F. "Very common in some localities near Wotton; partial to high rough grounds and boggy places." V.R.P. Near Stroud. M.G.M. SOMERSET. Bedminster. S.B. Common, near Wells. H.J.L. Sidcot, near Yatton. T.H.O.P. Weston-s.-m. G.R.C. Local, and not common in the district.

„ [ACTÆON. Esp.] This has been recorded as a native of the district on the authority of the late Mr. M. Westcott of Wells, who writes as follows in the "*Naturalist,*" 1854, *p.* 37—"In the course of my rambles here (Wookey, near Wells), this

season, I took some of all our known 'British skippers:' I have seen most of them in other places about here, but the most rare is the 'Lulworth skipper,' *P. Actaeon.*'" Dr. Livett suggests the probability of dark specimens of *linea* having been mistaken for *Actaeon* by Mr. Westcott, which seems so likely, that I have not thought it advisable to include this very local insect in my list, without further evidence of its occurrence in the district.

Nocturni.

SMERINTHUS OCELLATUS. L. Generally distributed, but not very common.

" POPULI. L. Common everywhere.

" TILIÆ. L. Generally distributed, but not common.

ACHERONTIA ATROPOS. L. Reported from all parts of the district, the larvæ and pupæ being sometimes rather common in potatoe grounds. Mr. Vaughan once bred a specimen from a larvæ found under an *ash* tree on Durdham Down.

SPHINX CONVOLVULI. L. Generally distributed throughout both counties, and in some years almost common. With the exception of three taken by Mr. Sircom in a field near Brislington many years since, I have no record of the occurrence of the larvæ.

" LIGUSTRI. L. Common throughout the district in all its stages. I captured a curious dark variety flying over a honeysuckle at Stapleton, in which the usual dark dorsal line was quite obliterated.

DEILEPHILA GALII. W.V. Throughout the district, widely distributed, but scarce.

GLOS. Specimens have been reported from "Redland, by the late Mr. Mayes." G.H.; Durdham Down, by the Rev. Joseph Greene. "*Entomologist, Vol. V., p.* 182; near Stroud, in September 1870, by the Rev. G. Braund. [Also, from near Gloucester and other localities, beyond my limits.]

SOMERSET. Clevedon. G W.B.; Weston-super-Mare. G.R.C. and Mr. Aldridge. [Near Bridgewater, E. Newman. "*Zoologist,*" *Vol. XVI.* Bridgewater and Langport, J. C. Dale. "*Naturalist,*" 1837; Taunton, by Messrs. Crotch, T. Clark, and Rawlinson.]

DEILEPHILA LINEATA. Fab. GLOS. "One taken in a cottage at Almondsbury, May 1850." J.A.H. "One captured by the late Mr. Mayes at Redland, is now in the collection of Mr. Robert Mayes." [Two specimens from the Cotswolds, recorded by the Rev. E. Hallett Todd, in "*E. M. M.,*" *Vol. VII.*]

SOMERSET. "One specimen, taken in Clevedon many years ago, is now in my collection." G.W.B. "One captured flying over flowers at Weston-super-Mare is recorded by Mr. R. Aldridge in "*Entomologist,*" *Vol. V., p.* 169.

CHAEROCAMPA CELERIO. L. GLOS. A specimen taken by Mr. G. D. Thomas, in Ashley Road, Bristol, is in Mr. Vaughan's collection: in the same collection are three more local specimens of this rare species, two of which were captured by a lady in a garden at Henbury, and one taken in Mr. Vaughan's garden at Redland. The late Mr. Duck recorded (*Naturalist, Vol. III., p.* 85.) the capture of a specimen at Baptist Mills, near

Bristol, in August 1852. [It has also been taken near Cheltenham.]

SOMERSET. "A fine specimen was brought me (September 16th, 1869), by a lady, who caught it in her drawing room" at Weston-super-Mare. M. A. Mathew, "*E. M. M.*, *Vol. VI.* [Two specimens reported from Taunton, by Mr. Bidgood. "*Entomologist*," *Vol. II.*, *III.*]

CHAEROCAMPA PORCELLUS. L. GLOS. Clifton Down and Stapleton, scarce. A.E.H. Westbury. T.H.O.P. Redland. P.H.V.

SOMERSET. Brislington. R.F. Weston-s.-m. G.R.C. Not common in the district.

„ ELPENOR. L. GLOS. Scarce at Stapleton. A.E.H. "Common at Wotton-under-Edge, the larvæ sometimes numerous in gardens, the perfect insect partial to strawberry beds." V.R.P. Near Stonehouse. W.F.W.

SOMERSET. Brislington. R.F. "Near Bath, one specimen *at sugar*." J.G.R. Wells. H.J.L.

MACROGLOSSA STELLATARUM. L. Generally distributed, but not often abundant; sometimes plentiful at Clevedon and Weston-s.-m., among flowers of "Red Valerian."

„ FUCIFORMIS. L. GLOS. Clifton Down. E.S. Redland. P.H.V. Wotton-u.-e., scarce. V.R.P. Near Gloucester, J. Merrin.

SOMERSET. Scarce at Leigh Court, and in Portbury Woods. A.E.H. and R.F. Partial to flowers of Rhododendrons. Local.

„ BOMBYLIFORMIS. Esp. GLOS. Near Easton. S.B. Rare, near Almondsbury. J.A.H. [Occurs

near Gloucester. J. Merrin, "*Annual*," 1869. Also reported from Newnham, &c.] Scarce, and local.

SESIA MYOPÆFORMIS. Bork. GLOS. In orchards at Cotham. J.H. Stapleton. G.H. Bristol. Stainton's "Manual." Wotton-u.-e. V.R.P.

SOMERSET. Scarce at Brislington. W.H.G. Bedminster. S.B. Probably occurs in most old orchards.

„ CULICIFORMIS. L. SOMERSET. One specimen at Bedminster. R.F.

„ FORMICÆFORMIS. Esp. GLOS. Recorded by Sir W. V. Guise, from the neighbourhood of Gloucester; and by Mr. Merrin, from the banks of the Severn: both these localities may be beyond my limits, but the species will probably be found nearer Bristol if well looked for.

SOMERSET. "One specimen on the Somersetshire side of the New Cut, Bedminster." S.B.

„ ICHNEUMONIFORMIS. W. V. GLOS. Wotton-under-edge. V.R.P. Durdham Down, Bristol. W.H.G., and A.E.H.

SOMERSET. Near Weston-s.-m. G.R.C.

„ CYNIPIFORMIS. Och. GLOS. In the Gully, Durdham Down, scarce. W.H.G. Bristol. Stainton's "*Manual.*"

SOMERSET. "Leigh Woods, singly." F.D.W.

„ TIPULIFORMIS. Rather local, but common in gardens among old neglected currant bushes.

„ ANDRENIFORMIS Lasp. GLOS. A single specimen of this very rare "clear wing" was taken in the Gully, Durdham Down, by the late Mr. T. Wilkinson of Scarborough, many years since. At the time of capture it was mistaken for a variety of *S. cynipiformis*. Mr. E. G. Meek

informs me this specimen was in Mr Wilkinson's cabinet, labelled "taken near Bristol," when he purchased the collection, shortly after Mr. Wilkinson's decease.

SESIA BEMBECIFORMIS. Hüb. GLOS. Bristol. Stainton's "*Manual*," Vol. I. p. 103. I have seen traces in old sallow trunks at Frome Glen and elsewhere, supposed to have been caused by larvæ of this species, but have not heard of its having been found in the district. A.E.H.

„ APIFORMIS. L. GLOS. Easton, near Bristol. Scarce. S.B.

ZEUZERA ÆSCULI. L. Fortunately not common in the district.
GLOS. A few specimens at Stapleton. A.E.H. Redland. P.H.V. Westbury. T.H.O.P. Wotton-under-Edge. V.R.P.
SOMERSET. Leigh, one only. E.S.

COSSUS LIGNIPERDA. Fal. Common throughout the district; especially partial to ash trees on the Downs, near Bristol, where many fine trees have been destroyed by the larvæ of this species.

HEPIALUS HECTUS. Linn. GLOS. Almondsbury. J.A.H. Near Dursley. G.H. Wotton-under-Edge. V.R.P. Stonehouse. W.F.W.
SOMERSET. Leigh Woods, Brockley, Portishead, Wells, &c. Local, but common where found.

„ LUPULINUS. Linn. Abundant throughout the district.

„ SYLVINUS. Linn. GLOS. Durdham Down. A.E.H. Stapleton. G.H. Almondsbury. J.A.H. Wotton-under-Edge. V.R.P.
SOMERSET. Leigh Down and Nailsea. A.E.H. Brislington. R.F. Weston-super-Mare, &c. Local, and not common.

HEPIALUS [VELLEDA. Esp.] Not recorded in my district, but is common on the shores of the Bristol Channel, near Minehead, Somerset (just beyond my limits on the S. West), and will be probably found near Burnham and Weston if looked for at the proper time.

,, HUMULI. Common over mowing grass throughout the district, though not so abundant as formerly.

PROCRIS STATICES. GLOS. Common at Wotton-under-Edge and Callicroft. J.A.H. Wotton-under-Edge. V.R.P.

SOMERSET. Brockley Coombe. A.E.H. Weston-super-Mare. G.R.C. Near Wells. H.J.L. On grassy hill sides: local.

,, GERYON. Hüb. GLOS. Common in the Gully, Durdham Down. A.E.H. Near Painswick. W.F.W. Wotton-under-Edge. V.R.P.

SOMERSET Leigh Down. P.H.V. Clevedon. A.E.H. Local.

ZYGÆNA TRIFOLII. Esp. GLOS. Near Almondsbury, in fields where thistles grow. J.A.H. Marshy fields; Boiling Wells, Bristol. G.H. Abundant on rough ground near Stroud. M.G.M. Wotton-under-Edge. V.R.P.

SOMERSET. Near Portishead, among *Centaurea.* J.N.D. Weston-super-Mare. G.R.C. Local and not common.

,, LONICERÆ. Esp. GLOS. Near Stonehouse. W.F.W. "I do not think *Loniceræ* occurs in the Stroud district." M.G.M.

SOMERSET Rough, dry places about Portishead. G.H. Weston-super-Mare. G.R.C. I do not feel sure about some of the records of these two last named species, and should be glad of

further information. *Lonicera* is decidedly the scarcer species, and is only found I believe on a few dry hill sides. I have never taken it.

ZYGÆNA FILIPENDULÆ. Throughout the district, common.

NOLA CUCULLATELLA „ „ „ but local.

„ CONFUSALIS. H.S. (*Cristulalis Hub.*) SOMERSET. Weston-super-Mare: scarce and local. W.H.G. and G.R.C.

„ STRIGULA. W.V. GLOS. "Several specimens in the Gully, Durdham Down, in 1872; not seen since." W.H.G.

SOMERSET. Portishead Woods. J.N.D. Scarce and local.

NUDARIA MUNDANA. L. Throughout the district, common but local.

[SETINA IRRORELLA.] L. This species is said to occur at "Woodchat Park, Gloucestershire,"—Stainton's "*Manual*," *Vol. I., p.* 144. I do not know this locality, and have no other record in the district. It is possibly a misprint for *Woodchester* Park, near Stroud.

CALLIGENIA MINIATA. Forst. Throughout the district, but not common, and rather local.

[LITHOSIA MESOMELLA.] Reported from near Gloucester by Mr. Merrin (*Ent. Ann.* 1869), and Newnham by Mr. Bingham (*Intelligencer, Vol. IV.*), but no records in my district.

„ DEPLANA. Esp. GLOS. "This insect occurs in Wynwards fir copse, Old Down, near Almondsbury, but is rare." J.A H.

„ LURIDEOLA. Freit. (— *complanula, Dbl.*) Common everywhere throughout the district; especially partial to flowers of *Clematis vitalba*.

„ COMPLANA. GLOS. Durdham Down, rare. G.H. Bristol. Stainton's "*Manual*." Wotton-under-Edge. V.R.P.

SOMERSET. Clevedon. G.H. Weston-super-Mare. G.R.C. Scarce and local.

LITHOSIA GRISEOLA. Hüb. GLOS. Stapleton, Sea Mills, Westbury, Almondsbury, &c. Not common.

,, SOMERSET. Banks of the Avon below Leigh Woods, and Portishead. Not scarce in damp meadows.

,, ,, *Var.* STRAMINEOLA. Dbl. This variety occurs, less commonly, with the type, and I have also met with an intermediate form.

,, QUADRA. GLOS. A single specimen was taken some years ago by Mr. John Bolt, on a gas lamp in Bristol. The only record in the district.

,, RUBRICOLLIS. Throughout the district, but local, and nowhere common.

DEIOPEIA PULCHELLA. GLOS. "A fine male specimen was taken by my mother (an old entomologist) in a garden at Bishopston, Bristol, on September 10th, 1871."—J. B. Jarvis, in "*Entomologist,*" *Vol. V., p.* 414.

SOMERSET. One recorded by Mr. Stevens in 1847, in the "*Transactions of the Entomological Society, New Series,*" *Vol.* I.

EUCHELIA JACOBÆ. L. Abundant everywhere. In the Leigh Woods I have frequently found larvæ of this species feeding on coltsfoot (*Tussilago farfara*), even when there was plenty of the usual food plant (ragwort) within reach. The curious change of diet does not appear in this case to have produced any variation in the coloration of the moths, so far as I have observed.

CALLIMORPHA DOMINULA. L. GLOS. Henbury, scarce. G.H. Blaise Castle Woods. P.H.V. Bussage and Selsley Hill, near Stroud. M.G.M. Clifton

Down, one specimen. E.S. Near Woodchester. Mr. Mackey, (*E.M.M. Vol. II., p.* 47). Stonehouse. W.F.W. Local.

EUTHEMONIA RUSSULA. L. SOMERSET. Near Weston-s.-m. G.R.C. Milton Hill, near Wells. M. Westcott, "*Naturalist*," 1854. [Scarce near Exeter. Mr. Parfit].

CHELONIA PLANTAGINIS. L. GLOS. Almondsbury, scarce. J.A.H. Common near Wotton-under-Edge. J.A.H.—"Swarms in the woods by thousands; is in fact the commonest wood moth at Wotton-under-Edge." V.R.P. *In litt., March* 1878. Dursley, common. G.H. Near Stonehouse. W.F.W. Common on rough ground near Stroud. M.G.M.

SOMERSET. Weston-super-Mare. G.R.C. Local.

„ CAJA. L. Generally abundant, and not much subject to variation in colour or markings.

„ VILLICA. L. Throughout the district, but not very common.

ARCTIA FULIGINOSA. L. GLOS. Arley Hill, Bristol. J. Bolt. Durdham Down. G.H. Near Stonehouse. W.F.W. Wotton-under-Edge, scarce. V.R.P. SOMERSET. Leigh Woods. J.G. Clevedon. W.H.G. Weston-super-Mare. G.R.C. Bathampton. J.G.R. Scarce, and local.

„ MENDICA. L. Generally distributed, but not very common.

„ LUBRICIPEDA. L. Larvæ abundant in gardens throughout the district.

„ MENTHASTRI. W. V. Throughout the district: common.

LIPARIS CHRYSORRHŒA. L. GLOS. Four at light, at Redland. P.H.V. Almondsbury, scarce. J.A.H.

SOMERSET. Weston-super-Mare. G.R.C.

LIPARIS AURIFLUA. Fab. Abundant everywhere.

„ SALICIS. L. GLOS. Henbury. J. Bolt. "Two bred from larvæ found on small leaved willow, near Stroud." M.G.M.
SOMERSET. Leigh Woods, scarce. J.G. Wells. Dr. Livett. Scarce, and local.

„ MONACHA. L. GLOS. "Taken on Durdham Down, but probably the result of eggs and larvæ turned loose." P.H.V.
SOMERSET. Weston-super-Mare. W.H.G.

ORGYIA PUDIBUNDA. L. Throughout the district, but not abundant.

„ ANTIQUA. L. Abundant everywhere.

DEMAS CORYLI. L. GLOS. Durdham Down. P.H.V.
SOMERSET. Leigh Woods. J.G. Portishead. J.N.D. Scarce.

TRICHIURA CRATÆGI. L. GLOS. Scarce, near Bristol. P.H.V.
Stapleton. G.H. Ashley Hill, by Mr. Naish. G.H.
SOMERSET. "Leigh Woods, one specimen, 1876." E.S.

PŒCILOCAMPA POPULI. L. Generally distributed, and not uncommon, especially in the larval state.

ERIOGASTER LANESTRIS. L. do. do.

BOMBYX NEUSTRIA. L. do. do.

„ RUBI. L. do. do.

„ QUERCUS. L. Common everywhere. Mr. I. W. Clarke bred a fine series of varieties, including several of the form known as *Callunæ,* from a batch of ovae laid by a typical female of *Quercus, Linn.*

ODONESTIS POTATORIA. L. Common everywhere.

LASIOCAMPA QUERCIFOLIA. L. GLOS. Scarce at Baptist Mills, at light, 1874 and 1876. I.W.C. and G.H. Scarce at Wotton-under-Edge. V.R.P. One specimen near Stroud. M.G.M.

ENDROMIS VERSICOLOR. L. SOMERSET. Near Bristol. Stainton's "*Manual*" Mr. P. H. Vaughan tells me he has seen this beautiful species on the wing, near the top of Nightingale Valley, Leigh Woods, but did not succeed in capturing any. I have long sought it there in vain.

SATURNIA CARPINI. BORK. GLOS. "Huntingford, near Tortworth: the larvæ are found here on bramble." V.R.P.

SOMERSET. Brockley Coombe. A.E.H. and J.W.C. Weston-super-Mare. G.R.C. Scarce, the larvæ being occasionally met with on heaths.

On the supposed Inferior Oolite at Branch Huish, Radstock.

BY E. B. TAWNEY, Assoc. R. Sch. Mines.

Read before the Geological Section, February, 1878.

IN the memoir on East Somerset and the Bristol Coal-fields published by the Geological Survey in December, 1876, at p. 78, we read as follows:—

"Behind Branch Huish Farm 4-ft. 7-in. of Penarth beds are "shown, consisting of White Lias limestones capped by the Sun-bed "8 inches in thickness, overlain by 2 ft. of Lias, which again is "capped by 5 feet 9 inches of Inferior Oolite."

Again at p. 98 *ibid*:—

"Behind Branch Huish Farm, south of Radstock, a quarry "shows the following section:—

		ft.	in.
	Inferior Oolite limestones ...	5	9
Lower Lias	Corn-grit bed, conglomeratic ...	0	4
	,, ,, ,, ...	1	0
	Greenish and Brownish Corn-grit	0	1½
	,, ,, ,, ...	0	4
	Yellowish Corn-grit	0	3
Penarth beds	... ...	4	7

The latter section is said to be from Mr. Usher's notes.

On reading these passages it struck me at once that there had been some misapprehension.

On a former occasion I had described* a section near Branch Huish in which the upper beds were differently interpreted. It is true that the section was not measured in the same quarry, but there was every probability that it referred to the same beds. To make sure of the matter last autumn I paid another visit to the locality, having this time the advantage of the companionship of the Rev. H. H. Winwood, F.G.S., Hon. Sec. of the Bath Nat. Hist. Field Club.

We visited the quarry which I had measured previously, viz., the one by the Limekiln on the side of the tram incline, which leads down from the Writhlington Pit to the Frome Railway. It lies about a quarter of a mile N.N.W. of Branch Huish Farm. The beds there are practically the same as those in the disused quarry immediately at the back of the Farm in the occupation of Mrs. Box, as the following section will show. Both quarries of course are S.S.W. of Radstock.

Section behind Branch Huish Farm :—

M. Lias.	6ft.	Yellowish ironshot limestone	*Am. latæcosta, Jamesoni, hybridus, Gryph. Maccullochi Pholad. ambigua, T. numismalis.*
	3-6in.	Pale marly limestone with phosph. concretions.	
(Planorbis Zone) L. Lias.	4in.	Thin brown shale.	
	3⅛in.	Yellowish limestone, bluish core. Corn-grit.	
	¼in.	Shale parting	
	3½in.	Brownish limestone. Corn-grit. *Ostr. Hisingeri.*	
	4in.	Thin brown shale.	
	10in.	Yellowish brown limestones, 2-3 courses, Corn-grits	
	1in.	Clay parting.	

* Notes on the Lias in the neighbourhood of Radstock. *Proc. Br. Nat. Soc.*, vol. I., part 2., p. 186. [1875.]

WHITE LIAS;	8in.	"Sunbed" pale lithographic limestone, bluish core
	2in.	Whitish clay parting.
	2ft. 7in	White limestones, several courses.
	2½in.	Pale brown clay shales.
	3ft.	White limestones, split into thin bands,
	1ft. 1in	White marls, with thin limestone bands.
	1½ft.	White limestones.

At the base are about 9-ft. of White Lias. I have given the beds in full, in order to show how little lithological resemblance they have to the Penarth beds; there is indeed objection to the application of that term to the white Lias beds. At some future time I may recur to the subject, for the moment I may say that I do not consider the White Lias to belong to the Rhætic series. They are however, indiscriminately with the true Rhætic shales, classed as Penarth beds apparently throughout the Survey Memoir.

Above the White Lias come 2-ft. 4-in. of Ostræa beds (Planorbis zone) viz., five beds of "corn grit" as they are locally termed, with some shale partings. They contain *Ostræa Hisingeri* (*liassica*) and the Ammonite of the zone is found wherever the beds are sufficiently quarried. At the moment of our visit no fresh stone had been taken out apparently for some time. Fossils are easily found in the same beds in the other quarry, and were mentioned in the previous essay.

Above the corn-grits, comes a bed with phosphatic concretions, this is the bed (e) of the former section, and is the boundary between the Middle and Lower Lias (*loc. cit.* p. 187.)

We now arrive at the ironshot limestones, classed in the Survey Memoir as Inferior Oolite. The few fossils which we cited, are sufficient proof that it belongs to the Jamesoni zone of Middle Lias. The list of fossils might be easily increased if there were any object in it. The beds are evidently the same as in the adjacent limekiln quarry,—have precisely the same aspect, and are about the same thickness. They are more fully described in the

former notice, and are the same beds as are seen in the well-known Mungar quarry, W. of Radstock.

They are surmounted by a few feet of brownish clays in both the Huish quarries; this clay we formerly classed with the Upper Lias; no fossils have been found; they have been previously alluded to (*loc. cit.* p. 178 and 188.)

Perhaps I should apologise for bringing so small a matter before the Society, but it is a case where fossil evidence is so abundant and so palpable, that any member however unpractised, may easily draw his lines after a little careful collecting from beds *in situ*.

On an Excavation at the Bristol Water Works Pumping Station, Clifton.

BY E. TAWNEY.

THE following section was pointed out to me, as worthy of examination, by Mr. Christopher Thomas, a Director of the Bristol Water Works Company; for whose further aid in the matter I am much indebted. It occurs at their Pumping Station in Oakfield Road, adjacent to the engine house. An excavation 27-ft. deep has here been made for erection of a new engine.

The material taken out was carted away as rapidly as the navvies excavated it, so that very little material has been examined, and that the lower beds chiefly; the upper part has been already cut to a vertical face, and the stuff carried away before I saw the section. For the upper beds then, one has been confined to such small pieces as could be picked out without interfering with the work. Moreover access could only be conveniently obtained when the men were not engaged, *e.g.*, during dinner hour. The opportunity for finding fossils has therefore not been a very good one. There is sufficient, however, to identify the beds.

The beds dip towards N.W. at an angle of about 5°. The excavation shows on the S. side that a fault runs under the engine house, and the top of Upper Park Street, forming the boundary on this side of the Lias patch which is seen on Sander's

map as a narrow strip running out from the Cotham outlier. As the S. boundary of this is due to a fault with a throw of over 20-ft., so is probably the N. one, for in the field opposite where houses have now just been built, are the red marls with celestine layers precisely as on the S. side of our excavation.

In an excavation in Hanbury Road where stone is quarried for these houses, below the red marls with celestine come in the the conglomeratic limestones as in the cutting at Clifton Station.

	1′-5″	Made soil.
INFRALIAS.	3″	White argillaceous Lias limestone.
	1′-1″	Pale greenish and brownish clay.
	2″	Pale Lias limestone.
	6″	Laminated bluish and brown clay.
RHÆTIC.	8″	" Landscape bed," concretionary surface.
	1-ft.	Laminated bluish and brown clays.
	8″	Two beds whitish argillaceous limestone with clay between.
	3-ft.	Pale greenish to brown laminated clays.
	2′-3″	Greenish-grey argillaceous limestone. Estuarine series. Plant remains.
		Clay.
		Thin pale grey limestone, *Estheria minuta*.
		Pale clays, and laminated limestones.
		Pale yellowish limestone with bluish heart. *Insect* wings.
	1-ft.	Dark grey shales
	6″	Dark bluish grey siliceous limestones. *Av. contorta.*
	7-ft.	Black stiff laminated clays. At the base are fish-teeth.—*Av. contorta. Cardium Rhæticum. Placunopsis, Ax. elongatus, A. cloacinus, Gyrolepis.*
KEUPER.	9-ft.	Light green micaceous and mottled marls.
	1′-2 ft.	Red marls.

At the base are seen the red marls, the excavation only cuts into them for the depth of a couple of feet: above them are pale green marls, which are evidently the same beds as in the Aust-Cliff section come between the red marls and the bone-bed. They are in the vertical sections of the Geological Survey classed as Rhætic. I prefer, however, to leave them in the Keuper, as they are without fossils (except the mammal tooth at Watchet,) the coming in of which in the Aust bone bed is so marked, while they are identical in appearance with the green layers alternating with the red marls.

Taking into account the dip of the beds there is not sufficient height for the Rhætic beds to have cropped out before the red marls of Hanbury and Alexandra roads come in, so that a fault must be here as on the S. The dip of the Rhætics was obtained not by instrument, but from the different level of the beds on opposite sides of the excavation, advantage being taken of the base-lines set out for the work; it is probably due to the dislocation, for the New Red beds seem approximately horizontal in the immediate district.

There is a sudden change at the top of the green marls, the succeeding beds being stiff black clays; the line of junction is hard and well marked, but it is one of erosion, apparently, for the green beds have been cracked and fissured for a few inches, and into these irregular fissures the black sediments have been carried with their fossils (fish scales and teeth) filling up every cranny: there is no mixture however, the limiting outlines are always distinct. There was a complete absence of fossils in the green-mottled micaceous marls, here they become abundant.

There is no distinct conglomeratic bone bed as at Aust, but some of the usual fish-remains occur immediately with the commencement of the dark sediments. No coprolites were seen, but probably would have been found if the search had not been confined to a few little pieces taken out of the vertical sides of the pit. The scales of fish occur too scattered throughout the dark

sediment; examples of *Avicula contorta*, and *Placunopsis alpina* were particularly abundant and good.

The next beds we must notice are in the table united by a bracket, these are considered estuarine, they are light buff colored thin limestones with clayey partings. The elytra of insects, which seem to occur in more than one bed, and that of *Estheria minuta*, are the reason of its being so classed. These crustacea I have found on Montpelier Hill in abundance (where the Rhætic section is very similar); doubtless this bed may have been observed in intermediate position by others, *e.g.*, it ought to occur on the slopes of the Cotham ridge. It should be well searched for insects if any exposure of it is seen.

In the clays above I found no fossils. The "Cotham Marble," or "landscape-bed" is well developed; it contains fish-scales, &c., as at Aust. The top of the section, *i.e.*, all above the landscape-bed are classed as planorbis-zone. This bed is the most convenient to choose as division between the Rhætic and L. Lias. In the landscape-bed we have the *Saurichthys* so abundant throughout the Rhætic, while it has *Pholidophorus Higginsi*, *nitidus* and *Legnonotus Cothamensis* peculiar to itself. Some remains of the latter rare fish, 3 or 4 mandibles and crushed scales, I found last year in this bed at Aust. That the peculiar surface of the bed is not due to erosion, has been noticed by Mr. Woodward, (Mem. Geol. Survey, Somersetshire, 1876, p. 73.)

On Professor Alexander Graham Bell's Articulating Telephone.

By WM. LANT CARPENTER, B.A., B.Sc., F.C.S.

Read October 4th, 1877.

IN order to understand this wonderful little instrument—by which, speaking in general terms, sound is converted into electricity which travels along an ordinary conducting wire and is reconverted into sound at the receiving end, so that speech is possible between two points many miles apart—a clear understanding of certain acoustical and electrical facts, and of their bearing upon each other, is necessary. I therefore propose to remind you of some of these before proceeding to describe and explain the mode of action of the telephone itself.

And first, with regard to sound. It is well known, and may be readily proved experimentally, that sound travels through the air at a rate somewhat exceeding 1,100 feet per second, the exact velocity increasing with a rise in the temperature of the air. In water, the velocity is about four times greater; in steel, sixteen times; and in pinewood, ten times. The transmission of sound through rods of wood was shown more than twenty years ago by a Telephonic Concert at the Royal Polytechnic, in London. Four musical instruments were placed in the basement of the building, and

to each was attached a rod of wood about one inch square, which, passing through the intermediate rooms, terminated just above the floor of the lecture-room in the topmost story. When the instruments were played, an auditor placing his ear on the upper ends of the rods successively, heard each instrument, and when sounding-boards were placed in contact with the rod-ends, the vibrations coming through the rods were transferred to the air, and fell upon the ears of the audience in the form of musical sounds. The common toy telephone, now so largely sold, is merely another illustration of this. It consists of two boxes united by a string which passes through the bottom of each. When the string is stretched tightly, and a person speaks in one box, what is said can be heard by an ear applied at the other, the sound vibrations being mechanically conveyed along the string. In this way conversation has been carried on between points one thousand feet apart.

It can very easily be shown that a mechanical movement, or series of vibrations, is set up in any substance whenever sound is transmitted through it. As one experimental proof may be quoted the fact that if a glass tumbler or bell which gives out a particular note when sounded, be taken, and that same note is produced by other means—the human voice, for instance—in close proximity to it, the bell can be broken by the violent vibrations set up in it, which have travelled through the air. No effect is produced upon it if a note is sounded, however loud, other than that to which it answers. This fact is susceptible of many curious applications; and as another instance of sympathetic vibrations may be mentioned the case of two clocks, which, although going at slightly different rates, will adjust themselves to go precisely synchronously, if they are within reach of each others pendulum vibrations.

The *loudness* of a sound depends upon the amplitude or size of these vibrations. The *pitch* of a sound on the other hand, depends wholly upon the number of vibrations per second which produce it; and if one of two sounds consists of twice as many vibrations per

second as the other one, they differ in pitch by the interval called in music an octave. A tuning fork, which vibrates 256 times in one second, produces the standard or concert pitch for the C on the added line below the treble staff; and the C in the middle of the treble staff, is caused by 512 vibrations per second. The lowest audible continuous sound is due to 23 vibrations per second, and the highest limit of audible sounds for man is about 38,000 vibrations per second. The range of a 7-octave pianoforte, F to F, is from 42 to 5,460 vibrations per second.

Sounds differ from each other not only in intensity and pitch but also in another respect. No one can ever mistake the sound of a violin or a horn for that of any other instrument, although they may sound the same note, *i.e.*, produce the same number of vibrations per second, and no two persons have voices alike. This difference in tone which enables us to identify an instrument by its sound, or a friend by his voice, is called quality of tone, or *timbre*. We are indebted to the great German physicist, Helmholtz, for the explanation of this phenomenon. He showed that a musical sound is very rarely a simple tone, but is made up of several tones, sometimes as many as ten or even fifteen, varying in intensity and pitch. The lowest sound, which is also the strongest, is called the *fundamental*, and is the one referred to in speaking of the pitch of a sound. The higher sounds that accompany it are called *overtones*, and they are simple multiples of the fundamental, *i.e.*, are 2, 3, 4, &c., times the number of vibrations of it. It has been clearly demonstrated that the character or quality of a sound depends altogether upon the number and intensity of the overtones associated with the fundamental.

To recapitulate.—Sounds vary (1) in intensity, according to the amplitude of the vibrations; (2) in pitch, according to the number of vibrations in a unit of time; and (3) in timbre or quality, according to the number of overtones associated with the fundamental note. We shall see presently how all these variations are

faithfully transmitted by means of the articulating electric telephone.

I now pass to certain electrical facts, and their bearing upon the telephone. The intimate relation existing between electricity and magnetism is probably well known to every one present. If a copper wire be laid near and parallel to a magnetic needle which is free to move, and a current of electricity is sent along the wire, the needle is deflected to one side or the other according to the direction of the current. This is the principle upon which galvanometers are constructed, and which formed the basis of the early electric-telegraph instruments. The converse of this is also true, viz., that if a bar magnet be brought near to and across a copper wire, a current of electricity is originated in the wire.

Through the kindness of my friend, Mr. S. P. Thompson, I am enabled to show you this experimentally. I have here a hollow coil of wire, the ends of which are connected with a delicate galvanometer, whose needle carries a small mirror, and matters are so arranged that the movement of the needle will be made evident to you by the traversing of the spot of light reflected from the mirror along a scale. When a bar magnet is inserted into the coil of wire, a current of electricity is set up in the wire, as you will see [The experiment was here performed.] The current is of very short duration, and when the magnet is withdrawn from the coil another current traverses the wire, but in an opposite direction to the first.

Now, if the bar magnet is allowed to remain in the coil of wire, and any substance which affects, or is affected by, the magnetism of the magnet, is brought within the range of the magnetic field, a current of electricity is also set up in the coil of wire. Such an alteration in the magnetic field is readily produced by bringing a piece of iron or steel near to one pole of the magnet. The current thus set up is weaker than the one first described; but I hope to make it visible to you. [The experiment was here performed.]

We are now, I think, in a position to understand the present form of the Articulating Telephone, a pair of which I have here.

Unlike most telegraphic instruments, the transmitting and receiving instruments are identical in construction, and each may be used for either purpose. It consists essentially of three parts. (1) A steel bar magnet; (2) a coil of thin insulated wire wound on a bobbin, placed over one end of the magnet; (3) a thin iron disc or diaphragm, placed very close to, but not actually in contact with, the same pole of the magnet. The whole is enclosed in a wooden case, with a trumpet-shaped mouthpiece, and the ends of the coil of wire terminate in binding-screws, to which are attached the conducting wires connected with the instrument at the distant station. The usual dimensions of the parts are,—magnet, 4 inches long, ⅜ to ½ inch diameter; disc, 2¼ to 2½ inches diameter: the kind of iron known as "Ferrotype" by photographers, answers best. The wire should be No. 36 guage, silk covered, and about 1½ to 2 oz. should be wound on the bobbin.

The explanation of the mode of action of the telephone is very simple. When speech is uttered into the mouthpiece, the iron disc or diaphragm is thrown into vibration, (the sound waves being carried from the larynx through the air and striking upon the disc) and alternately approaches closer to and recedes from the end of the magnet. Each of these movements causes a change in the magnetic field, and consequently the induction of a feeble current of electricity in the coil of wire. This current travels along the conducting wire to the receiving station, where it enters the other telephone, and travels round its coil. The magnetisation of this magnet is thereby disturbed, and its attraction for its diaphragm increased or diminished, causing the diaphragm to move. It will be readily seen, then, that the succession of currents thus arriving will cause the receiving diaphragm to vibrate exactly as the transmitting one does. The air in contact with the receiving diaphragm will receive precisely the same succession of impulses as those which fell upon the transmitter; and consequently an ear applied to the receiving telephone will receive these vibrations of the air in the form of sound, or articulate speech.

It cannot be too distinctly stated that there is no mechanical conveyance of sound vibrations. *The sound is converted into electricity,* which travels along the wire and is reconverted into sound at the other end. Conversation has been carried on between stations more than 200 miles apart on land, and also through 60 miles of submarine cable, with instruments constructed exactly like those described above, which I now show you. The currents so produced are very feeble; Mr. Gavey, of the Bristol Post Office, tells me that he attempted to measure the strength of a telephone current, and estimates it at less than the one ten-millionth part of that produced by a pint Daniell's cell.

It is necessary that all extraneous noise should be carefully excluded, while conversation is being carried on by the telephone. It will then be found that speech is reproduced with perfect distinctness, and that different voices may be readily recognised through it. Singing, and instrumental musical tones may often be heard when articulate speech is inaudible, or at least indistinguishable.

One great objection to the use of the Telephone over busy lines arises from this fact;—a wire conveying a very feeble current, or none, placed near a wire over which a strong current is passing, is liable to be acted upon by the stronger current, through what is called Induced Electricity. Hence, a telephone wire near others conveying battery currents, draws induced currents into itself, and these, entering the receiving telephone, are there converted into sounds which are very like the pattering of hail against a window, and are quite enough to overpower the human voice. Hence though telephones can easily be used over single wires, conversation is much interfered with if the wire at any point in the circuit is near wires used for ordinary telegraphic purposes. Through the kindness of Mr. Sampson, (Postmaster of Bristol,) and of the Netham Chemical Co., I was enabled to verify this for myself on the private wire between our General Post Office, and the Netham Works.

Perhaps the most interesting part of this extremely simple, but none the less wonderful invention, is the manner in which Prof. Graham Bell arrived at it. Time will not, I fear, permit me to do more than give a very brief sketch of this,—which I had the advantage of hearing in the course of conversation with him.

Professor Bell, whom we are proud to claim as an Englishman, is the Director of a large College in the United States, where persons are trained in the methods of teaching deaf mutes to speak, by the system known as "visible speech." The first idea of this system was due to his father, A. M. Bell, of Edinburgh, the inventor of a universal alphabet, consisting of only 10 physiological symbols, for representing the action of the vocal organs, by combinations of which, all possible vocal sounds can be written down, and reproduced from the symbols by those acquainted with the alphabet. The application of this alphabet to teaching deaf mutes to speak, is due to Professor Graham Bell himself. In the course of his experiments he devised several methods of exhibiting optically the vibrations of sound, commencing with Koenig's manometric capsule, in which sounds spoken to the instrument temporarily alter the shape of a gas flame. The phonautograph of Léon Scott was then tried, and tracings corresponding to the various vowel sounds were obtained upon smoked glass. The membrane and bones of a human ear were then used, and a stylus of hay being attached to them, much better tracings were obtained.

Concurrently with these experiments, Professor Bell was engaged in repeating some experimental researches of Helmholtz on the analysis and synthesis of vowel sounds, in which several tuning-forks of different pitch were made to vibrate simultaneously by means of an electric current, and for this purpose he was led to study electro-telegraphic phenomena very closely. Having these separate investigations in his mind at the same time, Professor Bell conceived the idea that a membrane to which a piece of iron was attached, might, by sound, be made to vibrate that iron in

front of an electro-magnet, producing alterations in the intensity of the electrical current, which might be conveyed to a similar electro-magnet, membrane, and piece of iron, at a distant point causing audible vibrations there. Here you will see was the germ of the discovery of the Articulating Telephone, but the first results were unsatisfactory and discouraging. In the earlier forms the transmitting and receiving instruments were of different construction. It was soon found that articulation became more distinct as the size of the iron diaphragm glued to the vibrating membrane was increased, and finally the latter was discarded altogether, and an iron plate used instead. It was then found, as had been long anticipated, that the effects were equally audible when a rod of magnetised steel was substituted for the iron core of the permanent magnet;—and thus was reached the present form of the instrument which I have had the honour of bringing under your notice this evening.

WM. LANT CARPENTER.

POSTSCRIPT.

Since the above paper was read, a Lecture on the Telephone delivered by Professor Bell to the Society of Telegraph Engineers, on Oct. 31st, 1877, has been published by E. & F. N. Spon, 46, Charing Cross. In this will be found fuller details upon many of the points briefly touched upon in the above paper. In particular, the researches of Helmholtz are dwelt upon, and the attempts of Professor Bell to apply these to multiple telegraphy, increasing many-fold the carrying capacity of a single telegraph wire. In this curious arrangement, several pairs of tuning-forks, or steel reeds, were employed—each pair vibrated to a different note—and one of each pair was placed at each end of the circuit. As, at the receiving end, each instrument only answered to its own pair at the transmitting end, as many currents (*i.e.*, sets of telegraphic signals) could be sent along one wire simultaneously as there

were separate pairs of reeds or forks employed. This was the practical end which Professor Bell had in view, when he commenced his researches in Electric Telephony. He soon found it necessary to designate by distinct names a variety of electrical currents by which sound could be produced. The three primary varieties are designated, Intermittent, Pulsatory, and Undulatory. The conception of this last is entirely original with Professor Bell, who thus defines them ;—(*loc. cit. pp.* 4, 5, 6.)

An Intermittent current is characterised by the alternate presence and absence of electricity upon the circuit.

A Pulsatory current results from sudden or instantaneous changes in the intensity of a continuous current.

An Undulatory current, is a current of electricity, the intensity of which varies in a manner proportional to the velocity of the motion of a particle of air during the production of a sound.

It may be remarked here, that it is the Undulatory current which renders possible the transmission of articulate speech.

Currents may be "direct" or "reversed" according as the electrical impulses are all of one kind, or are alternately positive and negative. "Direct" currents may be still further distinguished as "positive" or "negative," according as the impulses are of one kind or of the other. Hence, Telephonic currents of electricity may be—

Intermittent	Direct	Positive 1	Positive	Intermittent	Current.
		Negative 2	Negative	„	„
		Reversed 3	Reversed	„	„
Pulsatory	Direct	Positive 4	Positive	Pulsatory	Current.
		Negative 5	Negative	„	„
		Reversed 6	Reversed	„	„
Undulatory	Direct	Positive 7	Positive	Undulatory	Current.
		Negative 8	Negative	„	„
		Reversed 9	Reversed	„	„

W. L. C.

Formation of Coal.

BY E. WETHERED, F.G.S., F.C.S.

Read November 1st, 1877.

CHEMICAL analysis shows that the combustible portion of coal consists of Carbon, Hydrogen, Oxygen, Sulphur, and a little Nitrogen, which with the ash make up the total composition.

In the following table the partial analysis of several kinds of coal is given, with that of wood: it is copied from Roscoe and Schorlemmer's chemistry.

Substance.	Carbon.	Hydrogen.	Oxygen and Nitrogen.
Wood	50·00	6·00	44·00
Irish Peat	60·02	5·88	34·10
Lignite from Cologne ...	66·96	5·25	27·76
Earthy Coal from Dax ...	74·20	5·89	16·99
Cannel Coal from Wigan ...	85·81	5·85	8·34
Newcastle Hartley	88·42	5·61	5·97
Welsh Anthracite	94·05	3·38	2·57

On referring to this table we observe that wood contains the same constituents as the coal; but as we descend towards Anthracite, we find that the proportion of Carbon increases, while the other constituents decrease. As we look down the table we

are struck with the gradual passage, so to speak, of one class of fuel into another: first, wood or peat into lignite, and then into coal. This transformation is not apparent, but real; in fact there is not a shadow of a doubt that coal, jet, and probably graphite, are the products of the metamorphoses of vegetable matter. This explanation is supported by microscopical investigations which reveal the actual wood structure.

The era of the coal formation is called the carboniferous, but seams are met with and worked in other formations. Mr. F. R. Mallet has* described a seam between the Tertiary Sandstones and schists of Sikkhim Himalayas.

The coalfield of Brora, in Scotland, is Oolitic, and was first worked in 1598.

It is, however, chiefly to the coal of the carboniferous period that I purpose to devote this paper.

Countless ages ago as was that time, the sun shone then as now; and was the means of giving to coal plants the carbon with which their structure is built up. This process is still going on, and takes place thus :—

Carbonic acid gas is constantly being supplied to the atmosphere in many ways: it is absorbed by plants, and when the rays of the sun strike them, it is decomposed into its constituent parts—oxygen and carbon, the latter being retained to enlarge the bulk of vegetation, while the former is returned to the atmosphere. In this way the sun imparts power: we burn wood and coal as fuel, in so doing, the carbon again unites with the oxygen from which it has been separated, (in the case of coal after millions of years of separation) with such force, that for every pound of carbon undergoing complete combustion, an amount of mechanical energy is set at liberty, equal to the raising of a 11,000,000 pound weight one foot high

The Flora. Of what kind was the flora of the Carboniferous

* Records of the Geological Survey of India, Vol. VII. Part 2, page 53.

age? I must ask you in imagination to descend a coal mine with me. Let us select a seam of our own Bristol coalfield, and there see what information we can gather; but we must remember that every seam varies as to the exact nature of the strata immediately over it. Before us is the coal A Fig 1, under it a bed of fireclay, in which we find a peculiar fossil root *Stigmaria ficoides*, associated with small markings which are probably other roots—this is characteristic of seams all over the world.

FIG. 1.

The *Stigmaria ficoides* is of a cylindrical form enclosed in a black coal-like envelope, the internal structure is seldom well preserved, all that presents itself to the eye is a calcareous mass inside the organic cylinder, which represents the woody part of the plant. The external surface is covered with small pits, from which rootlets were given off.

We will pass over the coal for the present, and examine next the bed over it. In the case before us it is a black shale four inches thick: in some instances these shales contain a large per centage of hydro-carbon, which have accumulated from the decomposition of the vegetable matter during its transformation into coal: in this fossils are not common. Next is bed *d*, a moderately hard "duns" in which are found reed-like fossils, termed by the miners "flags," but they appear to me to be the genus *Cordaites*. This fossil has a great resemblance to a reed, I have found them

over every seam that I have yet examined in the Bristol coalfield. Next follows a bed of harder duns *e*: in this are other fossils besides the one just described (there are a few others in the beds below), they are chiefly of the genus *Sigillaria, Sphenopteris,* and *Calamites approximatus.*

If we pass to another seam we find the flora over the coal slightly different. Thus if we take the Great Toad Vein which is above the last seam, we still find *Cordaites; Sigillaria* is much more abundant; *Asterophyllites* is common; *Lepidostrobus, Lepidophloios* and others also occur.

The Bristol coalfield is not so rich in plants as some others,—no trace of a fauna has yet been discovered. If we take the South Staffordshire coalfield we meet with an abundance of both, as proved by Mr. J. Ward, F.G.S., and others. In the black shale of the "deep mine ironstone," worked chiefly at Longton, good specimens of fish have been found, of which the genus Palœoniscus is characteristic.

The "Rag" mine at Fenton also contains fish remains, as do other shales and ironstones in the district. Of the Mollusca—Brachiopoda, Lamellibranchiata, Gasteropoda, Cephalopoda, and Annelida, are all well represented. The flora is abundant, but has not been so fully described as the fish. No matter into what part of the world we go, wherever coal occurs of carboniferous date, the similarity of the flora is most striking. While in the Black Warrior Coalfield of Alabama I collected specimens so familiar to me, that it was like meeting old friends.

The trees most numerous during the carboniferous period were the *Calamites, Sigillaria,* and *Lepidodendrons. Calamites* have long been considered to be allied closely to the modern Equisetaceæ or "Horse Tails," which view is supported by Mr. Carruthers; but Professor Williamson points out that they have no sheath to each joint of the stem, nor, probably, hygrometric (absorbing water) elaters to each spore which is the case with the Equisetaceæ. Calamites are always found hollow, except at the nodes: it has

been suggested that the stems grow so, which is correct for the elder trees, but when young there was a pith which gradually became ruptured owing to rapid growth. Next to the pith was a woody zone, composed of wood wedges separated by a prolongation of the pith: these converge at the nodes, and externally appear like furrows extending from one node to another. At the nodes were transverse partitions dividing the stem into divisions. As to the base, it has been contended that the rhizoma converged to a point, the internodes becoming smaller. I have specimens in my collection which have a truncated base, and one with rootlets attached: it is possible, however, that these have been broken near the termination. The latter are most abundant in the Upper Series of the Bristol Coalfield; but in the Pennant, those with a conical base are mostly met with: in every case, however, the internodes diminish as they near the base. Calamites were branching plants, but as to the nature of their leaves or whether they bore fruit is considered doubtful. Dr. Dawson considers that they grew in muddy flats or perhaps in water; this, however, is an open question which requires farther research. The Sigillaria and Lepidodendroid plants are now generally supposed to have a close resemblance in their structure, and are classed among the Lycopodiaceæ. They consist of a central medullary axis surrounded by other cylinders of barred vessels, a sort of middle bark; a vascular woody cylinder and an outer bark.

The vascular woody cylinder seems to have been of a very tough nature, and it is this which has been preserved, the outer bark and inner cylinders having disappeared in the great majority of specimens found. The Sigillaria are very abundant in some seams. They are first met with in Devonian rocks, and attain their maximum development during the Carboniferous period, they are unknown in the Permian. The fossil is characterised by longitudinal flutings which divide the wood tissue into ribs. I very much doubt whether these ribs extended through the outer bark; from specimens which I have seen underground, and from one in my collection, I am

inclined to think that in some species at any rate they did not. The ribs are generally, marked by scars of an oval or round shape having in the centre other small scars; these appear to me to present a tubical appearance when covered by bark.

The Lepidodendra are very similar to the last, but instead of being marked by flutings, the vascular woody cylinder was covered with a more or less hexagonal shaped scars. From these foliage was given off; but as the branches grew this appears to have dropped off, being confined only to the twigs, or rather their equivalents. A short time ago there was found in the roof of the "Two Foot" seam, Speedwell Pit, near Bristol, a very fine stem about six feet long with fructifications, all complete. A more perfect specimen I never saw, but the main branch was quite devoid of foliage, while those radiating off were covered, especially near the extremities, at which there was also a fruit.

I have now given an outline of the chief tree plants which flourished during the great Carboniferous age, there are many others as well as ferns which might be named, but it is needless in this paper to do so, and I will only add that they were mostly, if not all, flowerless.

The Climate. Coal is to be found in almost all parts of the world, including the Arctic regions; it is therefore obvious that the climates of the world must have great changes. Upon this point there is no doubt, as we have other instances of change of climate notably in the glacial epochs.

Several theories have been advanced to account for change of climate. One which formerly gained much credence, attributed it to the radiation of internal heat into space by which the earth has become gradually cooled down, in which case the older formations would have been warmer than the later ones.

It was again suggested that the change was due to an alteration in the position of the earth's axis, caused by the elevation of land between the poles and equator.

The theory adopted by the late Sir Chas. Lyell has gained

considerable favour among scientific men, and accounts for change of climate by an alteration in the distribution of land and sea. He contends, that were land massed about the equator, strong currents of hot air would be carried to the Arctic circle, and the climate there would be such that tropical plants could flourish. Other theories attribute the change to an alteration in the course of the gulf stream, but none of them have been deemed thoroughly satisfactory. Some years ago Geologists looked to astronomy to solve the problem, and the eccentricity of the earth's orbit was brought into question, but the idea never gained much attention till Mr. Croll reproduced it with additions.* He has shown that the eccentricity of the earth's orbit and the movement of the axis, together with other physical conditions, would quite account for the changes in climate which the earth has undergone so many times since the Creator first launched our planet into space.

What Plants formed Coal. The question as to which plants formed coal is a very difficult one to answer. Professor Huxley has stated that several sections of coal, microscopically examined, have revealed spores of plants, and I believe that the theory has been advanced, of coal being entirely formed of spores, at any rate the Bituminous portion of it. But I cannot conceive of small spores accumulating in such dense masses as to form seams of coal several feet thick. Professor Dana states that it would take 8-feet in depth of compact vegetable matter to make one foot of Bituminous coal, owing to shrinkage by decomposition and pressure.

I shall presently show that the vegetable matter forming coal has been submerged by water, and I could conceive of large accumulations of spores being carried down with the sediment of a river and being so deposited; but then there would be so much mud and sediment intermixed as to make the formation worthless as a coal, though a shale might result. In the Geological Magazine volume for 1875, is a paper by Mr. E. T. Newton, F.G.S., in

* "Climate and Time."

which he shows that Tasmanite and Australian White Coal examined by him, contained a number of "small seed-like bodies very similar to, although smaller than, the microspores of *Flemingites*."

The analysis of the White Coal he gives thus :—

Combustible matter	29·58
Ash	68·47
Water	1·95
	100·00

Now I submit that the term coal is wrongly applied here, as for fuel it would be worthless owing to the amount of ash: it is a shale, and may have been formed as I have described.

It may be that some Bituminous coals contain spores, but they form only a small portion of the whole mass: these spores have, by some, been considered similar to Lycopodium, but this is far from having been substantiated.

Dr. Dawson has ably treated this subject, but makes no reference to spores, he says,* "with respect to the plants which "have contributed the vegetable matter of the coal, these are "principally the Sigillariæ and Calamiteæ, but especially the former. "With these, however, are intermixed remains of most of the other "plants of the period, contributing, though in an inferior degree, "to the accumulation of the mass. This conclusion is confirmed "by facts derived from the associated beds, as for instance, the "prevalence of Stigmaria in the under clays, and of Sigillaria and "Calamites in the roof shales, and erect forests." He refers to the Stigmaria roots in the underclay, and later on calls attention to their size, from which we may gather that the trees were very large, if this be so, the underclay should be full of them; but whatever may be the case on the other side of the Atlantic, it is

* Q.J.G.S. l., p. 639, 1859.

seemingly not so in this country, they always occur, but not in masses; and I have frequently found Stigmaria in the roof of seams with other remains, which is important. Considerable weight has been attached by Dr. Dawson and others, to the Flora found over coal, giving a clue to its origin.

Now the belief is that the plants which formed coal grew on the spot where the coal now lies, and that the underclay was the soil in which they flourished; then if these plants were the same as those which we now find in a fossil state over the coal, one would expect to find them immediately over: such, however, is not so, with the exception of Cordaites. Erect forests are very rare, a stump *in situ* is not common, the majority having drifted into their present positions. In many seams of coal, what are termed "coalstones" occur. These are probably hollow trunks or branches of trees, chiefly Lycopodiaceæ, which have been filled with *debris* while in water, and at last, owing to the increased weight, have sunk into the coal-forming vegetation which had been submerged. The idea is suggested by the shape, and specimens have been found which remove all doubt as to their origin, a considerable number being Stigmaria. The envelope surrounding the nucleus of *debris* is that of epidermis, which resisted decay more than the other parts.

In other seams what appear to be bands of dirt occur in the coal, from a few inches to four feet long, and from one to three inches thick. These have much the same origin as coalstones, but in this case the hollow stem has not been all filled up, and the weight of the strata deposited over has pressed the cylinder flat, causing the sides to burst.

These facts appear to show that the Lycopodiaceæ, and probably Calamites, resisted decay more than did the coal-forming plants, and that they were placed, where now found, by accident. The vegetable matter (epidermis) in these coalstones has been partially formed into coal, but ought not to be taken for microscopical sections, with a view of gaining a knowledge of the structure of the

ıl in which they are found, as in my view an error will thereby made. To get this knowledge the actual coal must be examined. ›st coals are made up of layers of different degrees of blackness l structure. There are bright black compact layers, soft ›wnish black ones, and dull black coal.

A portion of the bright black layers from the Kingswood Great in on analysis gave :—

Ash	1·85
Fixed Carbon	75·50
Volatile matter	22·65
	100·00

ıcture, even ; very brittle ; when heat was applied in a closed cible the mass rose, gave off a bright flame for a considerable ıe, and a light bright black porous coke was left. The ash was ale red colour.

The next layer was of a black colour, but not bright ; compact, l fracture uneven. An analysis gave :—

Ash	2·85
Fixed Carbon	78·07
Volatile matter	19·08
	100·00

On applying heat a flame was given off, but it was not so bright in the previous example, the mass first rose a little when air was :luded, but soon subsided, leaving a small lump of fixed carbon. e ash was quite white.

Lastly, the "Motherin" Coal layer. This was very soft, of a ɾery black colour, and is often an inch thick. Analysis as lows :—

Ash	2·50
Fixed Carbon (a powder)	88·75
Volatile matter	8·75
	100·00

On applying heat, a little gas was given off which burnt with a blue flame; when the air was excluded, a blackish brown powder with little cohesion remained. The ash was snuff coloured.

As to the origin of these layers, I confess I find it difficult to account, but it is possible they represent different plants. They seldom run more than a few inches in length, and are not arranged in any regular order ; it will be observed that they differ much in chemical composition and form, a basis by which a coal may be judged at sight, Near a fault the layers are so crushed that it is difficult to distinguish them.

It is suggested that the plants forming coal were allied to those which, at the present time, grow in water and swamps, namely, reeds, mosses and ferns. The peat deposits of to-day are composed of moss, and these, if left to nature, might in time form coal. Such vegetation would be a mass so thick and compact, that sediment contained in the submerging water would not penetrate to any extent, and thus we can conceive a pure seam of coal of an equal thickness being formed thereby.

Now comes the question, how did this vegetable matter become coal, and by what agency did the metamorphosis take place. The conditions must have been such as to produce only partial decomposition ; had these plants decayed as vegetation does strewn on the earth's surface, their elements would have combined with the oxygen of the air, and gradually produced new combinations. But those which formed the coal, cannot have gone through the whole process of decay ; hence, decomposition must have taken place under water. Two propositions have been advanced to account for the accumulation of these plants in water.

e is, that they were washed into great fresh water lagoons, rapidly covered up with *debris*, brought down by rivers ving therein.

The other theory which I hold to be the correct one, was first pounded by M. J. A. De Luc, F.R.S., in 1793—95, it is, that l has been formed by the remains of plants which grew in the local- s where we now find it. This theory has been slightly modified to extent that vegetation grew at the mouth of a great river, that land sank below the sea level, and that the *debris* brought down the river covered the vegetation and was either deposited faster n the sinking of the land took place, and thus raised it ficiently above the water for fresh vegetation to grow, or the d must have ceased to sink, or perhaps have been again elevated ve the surface.

We may notice next the size of some of the American coal- ds which are in general much more extensive than those in eat Britain. The Pennsylvania coal-field embraces 20,000 are miles. The Illinois coal basin includes Indiana, and West ntucky, and extends over an area of 51,700 square miles. The io coalfield is stated by Dr. Newbury to cover over 10,000 are miles. Others again are much smaller, as the coal fields Tennissee, said to be 5,100 square miles.

These great areas we may compare with the areas of modern er-deltas, as it is in such situations we conceive that coal-beds may ve been formed. That of the Ganges is 48,404 square miles. ie Delta of the Mississippi is larger than that of the Nile; m the Gulf of Mexico northward for about 100 miles, there is great dead flat, covered with pine forest, swamps, and rshes; the river is subject to great floods during the spring lting of the snow on the mountains to its north; the water nes down with great rapidity sweeping the trees far into the lf, or distributing them over the Delta for hundreds of miles. ie carboniferous rivers were subject to similar floods as shown by e black layers of decayed vegetation so common in the rocks

and strata associated with coal seams. Trees were also washed down, and deposited where we now find them; so that in our large rivers of to-day we are able to see a repetition of what took place during the great coal forming era. Each flood of the Mississippi deposits a layer of mud over the vegetation growing in the submerged swamps, which, in time to come, will be a thin layer of black organic matter, or if in sufficient mass, a bed of coal; and the trees washed down by the river will remain as fossils in, and above the coal.

To return to the decomposition of vegetable matter. The process of decay must have been restricted by submergence, we see the process every day; stir up the stagnant water of a ditch, and bubbles of gas are given off, showing that a chemical change is going on. Vegetable matter is composed of Cellulose, the composition of which is Carbon 12, Hydrogen 20, Oxygen 10; and when decomposition takes place certain gases are evolved, the principal of which are Carbonic acid CO_2, (the black damp of the miner); Carbonic Oxide, CO, which we frequently see burning with a blue flame in fire-places; and Marsh Gas, CH_4, better known as light Carburetted Hydrogen; it has acquired the name of Marsh Gas, from the fact of its being given off from Marshes and beds of peat, sometimes in such volumes that it may be lighted.

Now imagine these gases to be given off from the submerged vegetable matter, what will be the result? For every molecule of Marsh Gas given off, only one atom of Carbon will be parted with, to four of Hydrogen, by this means the proportion of Carbon would soon increase, while the proportion of the Hydrogen would decrease, this is just what we have in our table. Much the same thing would take place with regard to Carbonic Acid, one atom of Carbon would be given off to two of Oxygen, decreasing the proportion of the latter, but increasing the former. This process could, however, only go on to a certain extent, viz., as long as the Carbon could find Oxygen or Hydrogen with

which to combine; when this point is reached the process stops.

Kinds of Coal.—We may class coals under the heads of Cannel, Anthracitic, and Bituminous; all the varieties contain the same constituents but differ in the proportions, and yet occur not only intermixed, but a seam may be Bituminous coal in one place, and Anthracitic in another. An instance of this is shown in the Welsh nine feet; near Cardiff it is semi-Bituminous, and then changes to a pure Anthracite in Carmarthenshire.

Again the Low Main Seam of Northumberland and Durham is met with as a steam coal in parts of Northumberland, and on the Tyne is a gas coal.* Many theories have been invented to account for these varieties of coal; the most notable of these refer the cause to pressure, or heat, or the two combined, the force being derived from faults or disturbance of strata and the heat from trap-rocks.

With regard to the pressure, it is well known that when a Bituminous coal nears a fault, it deteriorates and becomes soft, whereas if the above theory is correct, it should assume more the form of Anthracite.

As to the heat from trap-rocks, the occurrence of such even if not in immediate contact with a seam of coal, would, no doubt, cause an alteration, as distillation would result, but it is difficult to conceive of a large area being so affected; and it is well known that there are no igneous rocks near the Anthracite seams of South Wales.

But both the theories in question are set aside by Cannel and other varieties of coal occurring in close proximity to one another, a remarkable instance of which is seen in Daviesse County, Indiana, where a seam of Cannel lies close over a Bituminous one, so that it would have been impossible for one to be affected without the other.

May not Chemistry be consulted as to the secret. Most writers on this question appear to have lost sight of the effect the *debris*

* N. England Institute Mining Engineers, Vol. xxvi., p. 44—46.

brought down by the rivers which submerged the coal-forming vegetation, would have upon it. The plants would be in a dying state; they would be composed for the most part of Carbon, Hydrogen, and Oxygen. The Carbon would naturally tend to combine with other elements, but there would only be a limited number of atoms of Oxygen and Hydrogen available from the decomposing mass; it would therefore unite, if possible, with any available constituents which might be brought down by the water. Now suppose the water to contain sulphates (as all river waters do) say sulphate of Lime, the result would be that a certain amount of Carbon would leave the coal-forming mass, reduce the sulphate to sulphide by depriving it of its oxygen, and form Carbonic acid. Then the Carbonic acid would act on the sulphide, forming carbonate of lime (so abundant in the strata associated with coal) and sulphuretted Hydrogen gas would be liberated.

The soil carried down by the rivers would contain oxides of iron, some more than others; in fact there is little doubt that vast quantities existed in some of the Carboniferous rivers as shown by the deposits of iron bands.

The result of Ferric oxide coming into contact with decomposing vegetation, would be similar to the last reactions; Carbon would be taken, and carbonic acid formed by the reduction of Ferric oxide into Ferrous oxide.—The Ferrous oxide being soluble would be carried away, or more probably form a carbonate.

Again the carbonate would be decomposed by sulphuretted Hydrogen with the formation of iron Pyrites and carbonic acid. This last re-action accounts for the occurrence of Pyrites in coal.

Now what I contend for, is that if vegetation sufficient to form a bed of coal was submerged by water containing certain sulphates and Ferric oxide, even in moderate quantities, a seam of coal with a decreased per centage of Carbon would be formed, containing Pyrites; while on the other hand, were these compounds absent, the coal would have a larger percentage of Carbon, and little or no Pyrites, in fact, be more of an Anthracitic nature, while the former would be more Bituminous.

207-218 – "Bristol Fungi" part i extracted to complete set.

On Insect Sounds.

BY H. E. FRIPP, M.D.

AN amusing chapter on "The noises of Insects" in the second volume of the Treatise on Entomology and Natural History of Insects by Messrs. Kirby and Spence, commences with a paragraph which I here quote, as a fitting introduction to the observations which I have to offer on this subject.

"That insects, though they fill the air with a variety of sounds, have no voice, may seem to you a paradox, and you may be tempted to exclaim with the Roman naturalist, 'What, amidst this incessant diurnal hum of bees; this evening boom of beetles; this nocturnal buzz of gnats; this merry chirp of crickets and grasshoppers; this deafening drum of cicadæ, have insects no voice?' If by voice we understand sounds produced by the air expelled from lungs, which, passing through the larynx, is modified by the tongue and emitted from the mouth—it is even so. For no insect like the larger animals uses its mouth for utterance of any kind: in this respect they are all perfectly mute, and though incessantly noisy, are everlastingly silent. Of this fact the Stagyrite was not ignorant, since, denying them a voice, he attributes the sounds emitted by insects to another cause. But if we feel disposed to give a larger extent to this word; if we are of opinion that all sounds however

produced, by means of which animals determine those of their own species to certain actions, merit the name of voice, then I will grant that insects have a voice. But decide this question as we will, we all know that by some means or other, at certain seasons, and in various occasions, these little creatures make a great din in the world."

"In discussing this subject," adds the author whom I quote, "I shall consider the noises insects emit during their motions, when they are feeding or otherwise employed, when they are calling or commanding, or when they are under the influence of the passions, of fear, of anger, of sorrow, joy, or love."

Before I enlarge upon this text, let me point out that the uncertain sound which our author himself gives betrays an ambiguity of physiological definition of which Aristotle can scarcely be accused. With regard to the voices of animals, says the great naturalist, the case stands thus.—"Voice and tone are "different things, and again, speech differs from both. No "animal gives voice with any other organ than the larynx, therefore "all animals which have no lungs have no voice. But speech is "voice articulated by means of the tongue; the laryngeal voice "produces only vowel sounds: the tongue and lips produce "consonants. Speech is the combination of both, and man alone "speaks. Therefore no animals speak which have no truly mobile "tongue, although they can produce sounds with other parts of "their bodies."

Aristotle then proceeds to explain the production of sounds in various insects, and it is interesting to find that he distinctly ascribes the sound of the grasshopper to friction of the "springing legs." But as the respiratory tracheal system of the insect was then, and long after then, unknown, Aristotle supposed that insects did not breathe air in and out of their bodies, and explained the humming and buzzing noises as an internal rush of air to and fro through the narrow constricted part of the body between the thorax and abdomen. This action he illustrates by comparing it with the

plaything which boys construct out of a reed pipe pierced by a hole, over which a membrane has been fastened, so that when blown into a musical buzz is produced.

Returning now to the paragraph above quoted, the propositions therein contained seem to indicate that the insect is voiceless, because it emits no sound by the mouth ; but that, in so far as the sounds produced are understood and acted upon, the insect's claim to voice as a means of intercommunication (which implies *hearing* and *understanding*) must be granted. However plausible such an explanation may appear as a popular account of the matter, I believe the author to be in error on both points.

In the first place, his physiological definition of voice (viz., "sound produced by air expelled from the lung and passing through the larynx,") is obviously founded upon the vertebrate type of voice-organ. Now the insect, though not possessed of a lung, is provided with an infinitely more perfect respiratory organ than any of the lower *Vertebrata*, beside which it has *many* mouths for passage of air into and out of the body through tracheal tubes, and in some of these a laryngeal membrane is so arranged as to be thrown into vibrations which produce sound. If, therefore, the insect has no voice, it is not because of any essential difference from the vertebrate type of voice-organ. On the other hand no single vertebrate animal—excepting man—can *speak*, although instrumentally as capable as man himself of the movements by which articulation is effected (*e.g.* the parrot).

Our author has indeed added to his physiological definition other conditions which are *not* essential to voice, unless thereby be meant articulate speech, *viz.*, modification by the tongue, and emission by the mouth. Yet the larger animals use their mouths for utterance, and, in fact, do utter distinct vocal sounds, and even modulate these sounds, (the song of birds !) but are as guiltless of speech as the insect.

In the second place he grants the claim of insects to voice, (in the sense of speech, that is, of sound which communicates idea),

on the ground that its noises however produced (not necessarily laryngeal) are understood by its fellow insects, and thereby a relation of emotional or intellectual intercourse established. He adduces cries of alarm, irritation, pleasure, fear, command, &c., terms which imply subjective states of insect consciousness which affect the utterance or cessation of these sounds, and determine the conduct of other insects when they hear them. This is in fact to claim for the insect the possession of faculties which regulate the use of its voice, and which amount to a reasoning perception acting as a motive to its utterance of sounds. In a word, the physical significance of vocal sounds is not only admitted for such as are emitted by the mouth, but also extended to include sounds which are not even vocal, because they none the less attract attention and determine action. But if all voluntarily produced sounds are to be considered as having the intention of language, that is of signs by which feeling or idea is expressed, then neither oral utterance nor the possession of a voice-organ constitute necessary conditions of intercommunication, though our author pronounces the insect voiceless on these very tests.

That animals produce sounds characteristic of their species, and that they *are* affected by sounds is sufficiently apparent, and most strikingly so when they are on the watch to hunt and prey upon other animals. And they are notoriously most observant of the sounds uttered by those whom they seek to make their victims, or whose attack they themselves avoid. But the appreciation of sound in all such cases has for its motive an instinct quite opposed to any intercourse between these natural enemies; nor can there be the slightest pretence of reciprocity between the sound which an animal utters without any intention of betraying itself, and the purpose of the animal on the watch for its prey. Why then must we attribute a particular *meaning* to the cry of alarm as though it were a warning to its fellows, even if it actually has that effect? Why must the cry of pleasure *mean* an invitation to others to participate? Why grant any foundation of *psychical* significance

(beyond the feeling of the individual concerned) where any approach to language is out of the question? Why again restrict the effect of such sounds as signs of intercommunication to individuals of the same species only? And finally, why admit the exercise of faculties yet unproved, because we fancy that insects must have that mutual understanding brought about by states of consciousness of which we alone as speaking animals are cognisant.*

The connection between vocal utterance and speech has, for our comprehension, innumerable breaks of continuity, missing links which we can neither follow nor measure. And to infer that, because a sound is not emitted by the mouth, it is not speech, or that an oral utterance of voice is speech, helps us little to a definition of either. Between these totally distinct functions of voice and speech there intervene, firstly—the agreement between sounds and a correlative organ and faculty of *hearing*; secondly—a sequence of psychical phenomena beginning with subjective consciousness, and passing through unknown phases of mental re-action and re-direction of the original impulse under the control of the will: in short, all that we imply in the word cerebration.

Now it is clear that the meta-physical origin and attributes of speech cannot be predicated of any animal in whom no adequate instrument of cerebration has been found, still less when the existence of such an organ has been disproved. We know, on the contrary, that even in man articulate utterance is a painfully acquired result of training, and that it is acquired not merely by

* The assumption that mental consciousness is necessary to every kind of sensation is disproved by many facts. All organisms unprovided with brain or nervous system of any kind must necessarily be void of cerebral consciousness, though some low form of organic sensation can scarcely be denied to them. In *all reflex action* the excitation of the motor fibre is said to take place without the aid of consciousness. An impression from without penetrates by the route of some afferent nerve to the ganglionic centre with which it is connected, and thence passes to the efferent nerve, travelling by another route to a given destination. But some capacity of receiving the original impression must be attributed to the peripheral end of the afferent

imitative effort as in a parrot, but simultaneously with the development of the ideas of which words are arbitrary signs. And we know too, that an insect's voice undergoes no evolution in dependence upon its experience with external surrounding, but remains what it was from the beginning to the end of its life.

Observation also teaches us that a truly wonderful inter-communication is effected between insects by a subtle development of the tactile organs and the sense of touch, compared with which the sense of hearing is so obscure, that the existence of an organ of hearing in insects has been doubted by many naturalists, and discovered only recently in a few insects. It is further clear that for the perception of the monotone insect voice no complex organ of hearing is needed. And it is difficult to believe that a sound void of all inflection, and taken up by an organ incapable of receiving any varied modulation, can express much spontaneity of motive in an insect, or convey to its fellow insect the various emotional impressions which we distinguish by the words alarm, joy, anger, pleasure, command, and so forth. In the sequel of this paper some recent experiments and observations bearing upon this subject will be detailed.

It is impossible to accept the popular belief in the emotional significance of insect sounds, without at the same time admitting that such exercise of vocal function stretches far beyond any yet

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nerve, which must therefore be a local sense organ: for without local organic sensibility of the nerve end there could be no transmission to the ganglionic centre. The excitation of this ganglionic centre may vary in quality or quantity, according to the disposition of the peripheral end of the afferent nerve in the skin, mucous membrane, gland, parenchyme of viscera, &c., or according to some differential character of the nerve end. But the reflex acts following excitation of the same sensory fibre may be of the most varied kind, depending, perhaps, on the discharging power of the ganglionic centre under varying nature and intensity of excitation. Yet there is not only entire absence of consciousness on the part of the individual, but every reflex movement can be as readily produced in a decapitated insect, or any other animal, as in the uninjured animal.

known capacity of the organs of voice, hearing, and conscious "cerebration" of the insect.

The assertion that an insect is conscious of a purpose in the cry which it utters, and that the action of its fellow is determined by its perception of that purpose, places insect voice and movement above all modes of "reflex action." But in no instance is the fallacy so often involved in the reasoning "*post hoc ergo propter hoc*" more likely to be accepted for truth than in observation of insect life, where the means of testing the supposed connection are so inadequate, and the absence of proof so easily supplied by imagination. The study of nerve and brain organisation of insects has hardly been commenced, and the amount of psychical endowment with which this organisation may be credited, is still further from being settled. But we may assume it to be beyond doubt that the insect brain is fitted for functions of a higher order than simple reflex action. Supposing, therefore, the impression of sound received by an organ of hearing to be conveyed to some percipient centre, intervening as a brain ganglion somewhere in the circuit of sensation and reflex action, the question presents itself, "what happens in this central part?" Does consciousness of the impression begin here? If so, and the insect thus become aware of an external sound, is that consciousness *passive*: that is, does it simply accompany the original impression, informing the insect with a sense of sound, but without arousing it to any psychical act? If so, consciousness adds no significance to sensation. Does, on the contrary, this consciousness on the insect's part become a starting point of psychical acts influencing the further course of the reflex action, or diverting into fresh channels the original sensation, then the reflex action becomes compound, that is to say, the direct course and simple resolution of the impression into some accustomed reflex movement is interfered with and re-directed. Hence arises a further question: are we to conclude that the purely automatic action is so interrupted as to amount to an action directed by the volition of the insect? For

instance, when an insect performs any movement in apparent recognition of some sound uttered by its companion, is that movement directed by the insect's consciousness, or does it take place in direct response to the sound heard as a reflex of sensation, whose issue in any particular movement is determined not by effort of will, but by conditions of the bodily structure? The experiments to be cited will partly answer this question; but I may here remark that the absence of volition is strongly indicated by the fact that an insect does not vary its action according to circumstances, or repeat it from memory as the lasting effect of a long past impression, but only when the impression is repeated. If, on the contrary, an insect does so vary its action, and repeat it on the motive of subjective sensation, then the act is removed beyond the sphere of reflex function, since we cannot imagine an indefinite prolongation of reflex function.

It must be granted that insect brains possess faculties proportional to the capacity of their sensory organs. Hence the measure of psychical endowment may be guessed at by close study of the organs of touch, smell, sight, and hearing, and of their relation to the brain ganglia. It must also be conceded that in an insect, as in all animals possessed of adequate organisation, there must exist a proportionate sense of bodily well or ill being which prompts its action. Consequently that the various acts of its life are associated with the conditions of well or ill being imposed on it by external surrounding. But it is quite another thing to assume that pleasure or pain evinced by movements of the body have become subjective, and as such constitute motives of action or reflection on the part of the insect. To affirm for instance that the surprised cry of alarm is a deliberate vocal utterance intended to warn its companions of danger, or that the song which attracts one insect to another is literally a love speech or a war defiance, instead of an implanted instinct the purport of which reaches beyond its individual life, knowledge, or intention.

Until the physiology of insect brain has been satisfactorily

ascertained, we are not justified in inferring from observation of insect habits and actions, their possession of emotion, passion, intelligence such as our own, the conception of which we derive solely from experience of our own nature. For if *our* states of consciousness elude definition, how can we even surmise what passes in the brains of other animals? If the psychical phenomena of which we feel cognisant defy explanation by reference to any organic processes with which we are yet acquainted, how can we affirm that the thoughts and ways of insects are identical with ours, because we see them do what we think we should do under the same circumstances?

Enough has been said to show that no certain conclusions respecting the psychical significance of insect voice can be drawn from comparison between the voice of man and the lower animals, or between the known motives of human speech and the apparent motives of insect sounds. But I think we may gain a better comprehension of the general subject and a new interest in the particular case of insect sounds, by directing our attention to some recent researches on the physiological and physical conditions which concur with certain anatomical dispositions of the insect's body to the production of a true vocal function.

The physiological definition of animal voice may be thus shortly stated—sound produced by the vibration of some animal membrane thrown into unrestrained movement by a current of air flowing into or out of a respiratory apparatus. Under this definition the insect sounds, which may be called *voice*, are fewer in number and variety than the sounds produced by organs which are *not* connected with respiration. In the apparatus which may be called the laryngx of the insect, as in that of Vertebrata, a membrane closes the tube in which it is situate, with the exception of a slit in the centre; and the free edges of this slit constitute the vibrating solid which converts a continuous stream of air into an intermittent current.

The sound is produced by vibrations of the *air*, not of the

membrane; but as the number of air vibrations depends upon the times of vibration of the membrane, the pitch of the note given out depends upon the tension of the membrane. For the time of vibration varies inversely with the length of the membrane, and directly as the square root of the extending force. Where, as in the human larynx, provision is made for varying the tension of the membrane (by its attachment to moveable cartilages, and by the action of tightening and relaxing muscles) the pitch of the note can be so varied as to allow of a complete scale of sounds. And similarly, slight variations of pitch are provided for in certain insect organs, by arrangements for tightening the membrane, and probably also for increasing the force of the air current, which increases at the same time the tension of the membrane. But in the human voice-organ a remarkable addition to the larynx is made, which partly answers the purpose of the sound pipe of a reed instrument such as is fitted to our musical instruments (organ, clarionet, bassoon, &c.,) but which is more important for the facilities which it offers for regulation of the voice as in singing, and articulation as in speech. The larynx does not open directly on the surface of the body as in insects, but is situate below the cavities of the nose, mouth, and fauces, the several parts of which are constructed of elastic and moveable tissues, whilst the palate, tongue, cheeks, and lips are supplied with a variety of voluntary muscles, whereby an infinite variety of combined movements can be brought into play, and additional tones and modifications of tones produced. Thus the reed sound may be entirely avoided, and by help of the cavities above the larynx, a sound produced, as in whispering or muttering, which may be rendered articulate by the movement of the lips and lower jaw, or it can be turned into a hissing, by projecting the tip of the tongue between the front teeth, and opening the lips. This same hissing sound may issue even from the larynx, as in the case of the serpent.

The fundamental laryngeal or reed tone, nevertheless, constitutes

the real basis of voice. If the mouth be fully opened, and the cavities of fauces and mouth be fixed, the initial reed tone is greatly intensified by adding sonorous open tones or harmonics of the primary tone. The vowel sounds thus produced are compound tones, whose characteristic quality depends on the particular shape and position in which the mouth, jaw, and fauces are for the time retained. If the full reed tone be produced, and, together with the additional tones obtained from vibration produced above the larynx, be articulated by suitable movements, complete vocalization, comprising variously combined vowels and consonants, is the result. Each vowel sound has its ground note and harmonics, and if sounded with great power the added harmonies prevail so as to render the ground tone more sonorous; but in whispered speech the vowels are principally made up of the ground tone produced in the cavity of the mouth, through which air is gently breathed. Consonants are only noises formed by movements of the palate, lips, &c. Thus noise and tone are associated in the human voice.

Now in many insects—and notably bees, flies, gnats, and the wonderful singing cicada—the analogue of this human vocal organ is to be found in the breathing spiracles of its chest, two pairs of which are transformed into vocal organs: the tone produced is a reed sound, and the vocal membrane is in some insects furnished with muscles, and stretched upon an elastic ring, which arrangement enables the pitch to be varied. The insect has, in short, a singing voice, and instead of wanting a mouth, it has one or two pairs of mouths, whilst the vocal apparatus is enclosed in a considerable cavity which is resonant. In fact the insect in proportion to its size and weight has a vocal organ, the dimensions and power of which are on a scale immeasureably greater than in man.

It is, however, not a necessary inference that the insect apparatus is directed by any volition, though the insect seems to exercise its voice at will. Certain states of bodily sensation, may by reflex

influence liberate the apparatus from that repose which is its natural state, or may set it going simply by change of air current through the thoracic spiracles. Such reflex action may be associated with a passive consciousness, but the insect voice is probably as automatic as its breathing. If the head, wings, legs, and abdomen of a fly be cut off, and the mutilated trunk laid down on a table, its buzz may be heard as long as the thorax breathes!

But we too often confound the *physical* conditions and mechanism of voice with the *physiology* of vocalisation; and we are apt to forget that vocalisation (in the act of singing) as well as speech is essentially a series of co-ordinated muscle movements originated in man by *psychical* motives, and although the human vocal chords are operated upon by an acquired and highly complex automatic function, the whole operation is manifestly directed by the Will. We see this in the selection of notes out of an extended scale, as well as in the power of increasing the number of notes and in modifying their quality and *expression*. States of consciousness are thus associated with articulate speech and vocalisation for which an organ of hearing of corresponding subtlety is as necessary for guidance of the voice as sight is for governing movements of the body. But the insect has few notes of unvaried character, and just as the mutilated fly continues to buzz, so the perfect insect may chirp, croak, and buzz without hearing its own noises, as an artificial toy does. And there is great reason to believe that the greater number of insects are influenced by the vibrations communicated to their bodies in a more direct way than through an organ of hearing; as indeed our own *feeling* of vibratory sounds might convince us. And this, if true, would render any organ of speech or distinction of vibratory impressions as *sounds* unnecessary.

We may next consider those insect sounds which are not produced by vocal apparatus but which may be musical tones, or mere noises, according to the nature of the mechanism by which they are produced.

According to the physical definitions of sound, those made by

animals consist generally of noises, or of compounds of noise and tone, or of compounded tones.

Noises are sounds produced by the vibrations of bodies which do not swing with equal periodic movement. Tone is recognised when the sounding body moves with regular periodicity. Vibrations are periodic when in given intervals of time, a body swings with exactly the same number of to-and-fro movements (*e.g.* pendulum beat.)

The strength of a tone is conditioned by the amplitude of vibration; the pitch by the number of vibrations; the quality (timbre, colour) by the particular form of the periodic vibration.

The analysis of a compound tone produced by animals requires special experimental treatment, which cannot always be applied, and the distinctions of voice sounds has been from the time of Aristotle down to the present moment based upon the character of the instrument by which the sound is caused, rather than its physical character.

The most imperfect form of insect sound is the single beat, as in the case of the *Anobium*, or death tick, or the rustling sound or crackle of powerfully worked jaws of caterpillars and many insect larvæ when feeding. In these instances no respiratory organ is concerned, nor is the sound a musical tone. Many animal sounds which at first appear to be mere noise can be resolved by special physical apparatus into tones musically distinct, so that the distinction between noise and tone is reduced to this—that certain noises which can be so resolved are a complex of vibrations not resolved by the human ear, except with the aid of acoustic apparatus, and a portion not resolved by the insect ear.

For us sounds constitute *tone* when they are so distinguished by the human ear, whether this tone be produced by organs within or outside the body, and with or without co-operation of the respiratory organs. For example, the shrilling of the cricket, grasshopper, water bug, &c.; the chirp of a *crioceris*, the hum of bees, gnats, &c.

Distinguishing insect sounds by the mode in which they are instrumentally produced, we may classify them as 1. Stridulant tones, as of a rasp or file, the stridulation being produced by the rapid click of toothed processes. 2. Wing tones as simple vibration of air. 3. Voice, as a reed tone essentially consisting of vibration of membranes. 4. Noises, or interrupted concussion sounds, as when parts of the body are struck against each other, or against foreign bodies, or, as in some rare cases, air volumes expelled from the interior of the insect; or again, as in the clapping of wings in certain *acridia*, and the rustle and din of a locust swarm.

Before I enter upon the technical description and illustration of the organs by which insect sounds are produced, a word may be said upon the uses of these sounds.

All are agreed—naturalists, poets, philosophers, and physiologists,—that insect sounds, generally, are directly related with sexual instincts.

Dr. Hartman writes to a friend in June, 1871, as follows.—The drumming of the *cicada* is to be heard in all directions round me as I stand in the dense chesnut forest: hundreds of males hover about the height of a man from the ground, and I notice the females assembling from everywhere. In my garden I observed fifty larvæ of *cicada pruinosa* which were brought up in a dwarf pear tree, and I frequently saw females approach and set themselves down in their neighbourhood, whilst the males uttered their sonorous song. Darwin heard the sound on board the Beagle, a quarter of a mile distant from the shore, and Captain Hancock heard it more than a mile off. Darwin infers from his observations that the males enter into rivalry and competitorship, whilst the females exercised selection according as their fancy was stirred! The same distinguished naturalist states that when the cricket is alarmed at night he uses his voice to warn his neighbours. A large number of observations made on ants and bees, and other insects, may be found in his work on the Descent of Man.

Herman Muller repeatedly observed the females of *Eristalis*

sitting basking in the hot sunshine on a leaf or flower, whilst the male hovering perpendicularly above the female, and at the distance of about an inch, kept its position by rapid vibration of its wings, and uttered unceasingly its regular note. When it had persisted for many seconds together, it suddenly shot down upon the female uttering a higher note, and then returning with a half or quarter wheel to its original position above the female renewed its first tone. It however changed its position relatively to that of the female, by hovering with its body poised at right angles to the female, if it had previously taken a parallel position. Occasionally a second male would enter into competition. The female took the whole proceeding quite unconcernedly, or accepting the offered attention with a slight movement of separating its wings.

Professor Landois, in a most interesting work on Animal Sounds from which I am about to read a series of extracts, says, that in many cases the object of insect sounds is the preservation of the individual. As, for instance, when attacked by other animals it is an alarm cry. If a fly be caught it makes a loud and scared buzz such as is scarcely ever heard at any other time—bees and drones do the same. Many insects never give forth any sound except when irritated, as, for instance, the Longicornis, Crioceris, and Necrophorus. Flies and bees, on the contrary, are always ready to give voice. Dr. Landois also believes that insect sounds serve as means of mutual communication and understanding upon matters which are not immediately connected with sexual instincts. And in the case of social communities amongst insects, it is difficult to avoid this conclusion when reading the history of bees and ants.

The latest observations in England on habits and doings of ants, by Sir John Lubbook, may be referred to with interest. But in considering this intercommunication between individual insects, it must be borne in mind that what is called the common language or speech of each species, or genus, may be just as rightfully interpreted as the effect of a stimulus which affects each individual organisation in the same way—it may be gesture, a motion as well

as a sound, or it may be by contact of antennæ. If a true speech be claimed, it must be objected that the psychology of insects has not yet been placed on the only possible basis of brain physiology, on which such an hypothesis can be founded.

I now proceed to the consideration of certain physical phenomena explanatory of the various insect sounds.

The following account of an experimental enquiry instituted by Professor D. H. Landois on the shrill tones of insects, is taken from an interesting little volume published recently by this gentleman, and entitled "Animal Voices."

When the point or sharp edge of a penknife is drawn over the surface of a highly polished plate of metal or glass, a shrill musical sound is heard. On examining the track made by the penknife with a lens or under a microscope, it will be found to consist of a number of minute incisions situate very close together, which, with their interspaces, are disposed with a regularity proportioned to the greater or less uniformity of the tone heard. The astonishing minuteness of these incisions will be best understood from the fact that the experimentors counted in one case 150 in the space of one millimeter. They are obviously produced by the intermittent descent of the knife edge upon the polished metal surface, and the number of cuts equals that of the shocks or beats which produce the sound.

In the Annals of Physics and Chemistry (Poggendorf) Vol. cl., page 565, tables 7 and 9, Professor Landois has published a long series of experiments, accompanied by phototypes from photographs of a number of these sound lines, probably the first instance of sound being photographically represented. The plates which he found best for his experiments were made of thick glass well polished on the surface, which was variously prepared. In some cases a solution of gum arabic was poured over the surface in a very thin layer, and this, when well dried, was blackened over the flame of a petroleum lamp. In others the solution was blackened by addition of indian ink; in others, again, the surface was covered

with a film of iodised collodium, then dipped in a nitrate of silver bath, exposed to light and dried.

The prepared plate was arranged so as to be drawn steadily by clockwork along another larger glass plate, and a knife point was fixed in a frame so as to hang from above downwards, so that its sharp point rested on the prepared surface and nearly perpendicular to the plane of its motion. As often as the plate was set in motion a tone of definite pitch was heard, the pitch appearing to depend on the rapidity of movement of the glass plate and the weight or pressure of the knife point. The same result would, of course, be obtained if the knife point were moved on the glass.

In order to be able to determine the number of incisions made in a given time, and compare this with the pitch of the tone, the time which passed during the production of the sound line was accurately measured by means of a pendulum beating seconds, while at the same time the height of the note was taken down. On counting the fine incisions of the line, the result obtained was—as expected—that the *numder corresponded with ths number of vibrations of the tone produced*, small differences between the observed and the known number of vibrations being accounted for by inevitable imperfections of the experiment. The results of three trials are given in the following table.

Experiment.	Time in Seconds.	Tone produced.	Length of the line in milim.	No. of incisions in one m.m.	Vibrations counted.	Calculated	Difference.
1	11	f′	115	34	355	352	3
2	10	d″	74	80	592	594	2
3	8	f′	83	33	342	352	10

Many audible sounds which are constantly referred to the category of noises, prove on a closer examination to be undoubted

musical tones which may be distinguished with accuracy, but which cease rapidly and as suddenly change for other tones.

Now the phenomena of friction sounds and tones in the Articulata are exactly analogous. In crabs, spiders, beetles, crickets, &c., the fine notches which are found on their various file or rasp-like organs, correspond with the marks on the sound lines of the plates experimented upon, and over these file-notched organs some sharp edge, belonging to some other part of the body, is moved backwards and forwards. The tone produced bears exact relation to the fineness of the notches, and the rapidity with which the moving part of the apparatus is driven. It is observed, for instance, that when the movements of the thighs of the grasshopper begin rather slowly, the "s.r.r." tone is deeper than when the motion is more rapid; and the finer the notches, or the more rapid the movements, so much more acute are the tones given out by the cricket, beetles, bugs, &c.

If the number of notches and the length of the file be known, and also the time occupied by the movement of the organs, the pitch of the tone produced by the insect can be easily reckoned. And, conversely, other unknown quantities may be found as, *e.g.* the number of notches on the file can be reckoned from the data of pitch of tone, length of file, and time of motion.

If we call l. the length of the sound line or notched organ,
n. the number of notches to 1 millimeter.$=\frac{1}{25}$ inch,
t. the time occupied by friction on the notched line along 1 mm. of its length,
s. the number of vibrations of the note,

we obtain the formula $\frac{l \,.\, n}{t}=s$, the application of which to the sounds made by insects is of practical importance. Thus, for instance, let it be required to determine the pitch of sound produced by the *Cerambyx* (capricorn beetle). Professor Landois measured the length of the notched ridge on the *meso-pectus* of a male *Cerambyx moschatus*, the length of whose whole body was

$\frac{18}{25}$ of an inch, and found it be 1 'milimeter. He then counted the number of notches and found them to be 364, and finally determined the rate of movement of the sharp edge on its *antepectus* to be equal to 0.17 second. Thus, by formula, he calculated the number of separate beats $\frac{1 \times 364}{0.17} = 2141$ = the vibrations of the musical note d''''.

When the beetle worked his instrument faster or slower, the tone was raised or lowered accordingly.

The female of the same species had a notched ridge of $1\frac{1}{2}$mm. in length, and on this were counted 304 notches, or 202·6 for 1 mm. Taking the time as before ascertained at 0·17 second, we have $\frac{304}{0 \cdot 17} = 1783$ corresponding to the vibrations of the note a'''. Professor Landois remarks that every one may distinguish the note of the male as higher than that of the female.

The length of the notched ridge of *Cerambyx heros* is 3·4 mm., and the number of notches on it 238, that is 70 to the mm. The time was measured at 0·32 seconds. This insect's note is therefore $\frac{3 \cdot 4 \times 70}{0 \cdot 32} = 744$, which number corresponds to the tone f''. Even for the very smallest Cerambyx, whose note is too weak or too high for the human ear to hear, the tone may be calculated. For instance. the notched ridge of "*Gracilia pygmæa*" measures 0·375 mm. in length, and the number of notches 113, (therefore 301 to the mm.), the time occupied in friction was 0·08. Hence $\frac{113}{\cdot 08} = 1413$, which corresponds to the tone f'''. The same formula gives some idea of the notes of insects whose fossil remains still show the length of the notched ridges and number of notches thereon, if we assume the movement of the parts to have the same rapidity as is observed in living species.

2. *Tones produced by motion of the wings of insects.*

Many insects move their wings slowly in flight. *e.g.* the cabbage

butterfly about nine times a second, also the day flying Lepidoptera, none of whom make any sound. But if the wing membrane be very dry a fluttering or rustling sound is produced, notwithstanding the slowness of movement as, *e.g.* in the dragon fly, the sound being caused by contact of parts of one wing with the other. In the families of Diptera and Hymenoptera, a wonderful variety of sound produced by the motion of the wings is heard. The rapidity of wing motion is due to excessive development of muscle in the Thorax, and the wings cause sound in the same way as tongues of metal do when made to vibrate.

To determine the note of a free flying insect requires a very musical ear, and also long practise in recognising and distinguishing the note sounded by an insect flying rapidly by, as any body will find who tries. Dr. Landois advises the observer to hum lightly to himself the tone a′, so as to catch the tone of a passing insect, which he says can, with practise, be done. Thus we may ascertain, for instance, the note of the common fly f′, and the honey bee a′ The wing tone which each individual gives is nearly constant; but the size of the individuals of the same species exercises some influence upon the pitch of the tone, which, however, being of little moment, may be left out of consideration. When the insect is very tired, it makes less rapid wing movements and its note sinks. In the case of a bee which had been much used up in experiments and was obviously exhausted, its natural tone a′ sank to e′ a fourth below.

When the sexes of the same species differ much in size, so does the wing tone. Thus the small male of Bombus terrestris has for its note a′, whilst its much bigger mate sings an octave deeper— This depends of course on the size of the wing and the greater or less rapidity of its movement. But there are small species of insects which have a considerably deeper tone than some larger species. The small Hœmatopota pluvialis (a bee) gives the tone h, whilst the much larger bee gives a tone more than an octave higher. This depends on the number of wing vibrations in a given time.

Sometimes additional sounds are heard with the wing-tone, as, *e.g.* in the red-winged grasshopper Pachytylus Stridulus, where the clicking sound produced by friction of the root of the posterior wing against the wing-cover predominates. The contrary may be observed in Stratiomya Chameleon (water fly) where the wing tone overpowers an accompanying crackling or rustling sound of the roots of the wing.

A different method of producing sound, by vibration of the insect's wing, is that which closely resembles the bowing of a stringed instrument, as noticed in the friction tone of the cricket where the anterior pair of wings, or elytra, are set in vibration by the friction of their file notched ribs. Any difference of tone in these insects can only be caused by slower or more rapid friction—every individual keeps generally to one note, but those which are smaller make a finer note than the larger individuals. The same occurs in the grasshopper whose wing cases are set in vibration by friction of the thighs of the third pair of legs.—Forte and piano, crescendo, decrescendo, as well as a rise of tone by more rapid friction, are possible with this arrangement.

3. *The number of vibrations* of the insect's wing is far too rapid to be counted by sight, except in a very few cases. But this difficulty may be solved in two ways.—

Marey in his Memoir on the Flight of Insects and Birds, (ann: des Sciences Natur: 5th Ser. Zool. T. xii., p. 49,50), was the first to determine the number of vibrations by help of a graphic method. The insect was so fixed as to allow the tip of its wing to remain in contact with the smoked surface of a cylinder, which was set in motion by clockwork. Each movement of the wing swept the smoked surface of the advancing cylinder, leaving its line of contact visibly marked. In this way Marey found that the greatest number of vibrations was that of the house fly, *viz.*, 330 in a second, and the least number that of the cabbage butterfly, *viz.*, 9, Marey considers that the number of vibrations cannot be ascertained by determining the note, because the hum of the insect arises from

several separate sources. Dr. Landois, admitting it to be difficult to distinguish the insect note from the wing-tone, says, that he distinctly recognises with his ear the flight tone e′, f′ or g′ of the fly, whilst its *voice* is capable of modulation between h′, c″, and b′, so that Marey's counted vibrations 330 agreed with the flight tone e′ heard by Dr. Landois.

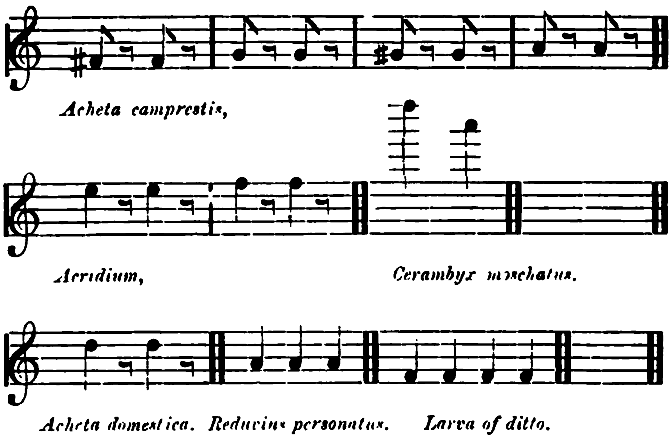
TABLE OF NUMBER OF VIBRATIONS CORRESPONDING TO MUSICAL TONES.

The letters C, D, E, F, G, H, in the column to the left are the several notes of the octave. H in German notation stands for B of the English scale.

	Lowest Octave. $C_{,}$—$H_{,}$	Second Octave. C—H	Third Octave. c—h	Fourth Octave. c′—h′	Fifth Octave. c″—h″	Sixth Octave. c‴—h‴	Seventh Octave. c⁗—h⁗
C	33	66	132	264	528	1056	2112
D	37.125	74.25	148.5	297	594	1188	2376
E	41.25	82.5	165	330	660	1320	2640
F	44	88	176	352	704	1408	2816
G	49.5	99	198	396	792	1584	3168
A	55	110	220	440	880	1760	3520
H	61.875	123.75	247.5	495	990	1980	3960

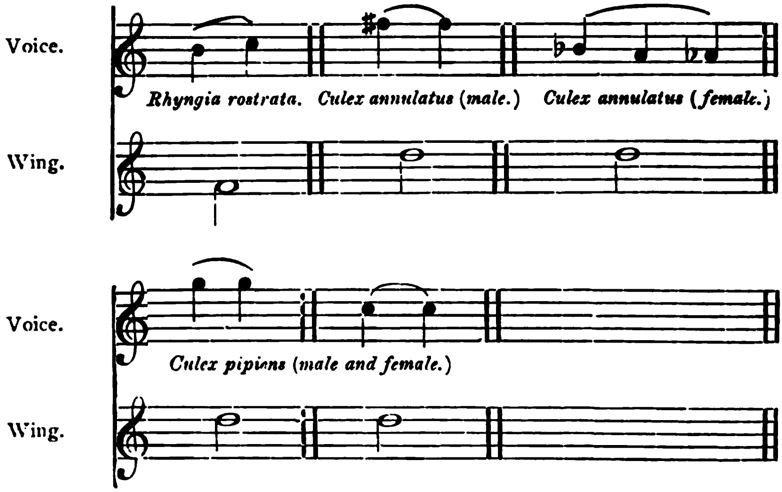
By reference to the accompanying table of musical notes and their corresponding vibrations, it becomes easy to determine the number of vibrations of the insect's wing, provided that the flight tone be distinguished from the voice.—Besides the instance of the fly, Dr. Landois states that the female of *Bombus muscorum* (moss bee) hums in flight the note a, which is equivalent to 220 strokes of the wing per second. The honey bee sounds with its wing motion the note a′, and therefore makes 440 per second, which is just double the number of vibrations made by the moss bee.

Rasp-Tones of Cricket and Beetle.

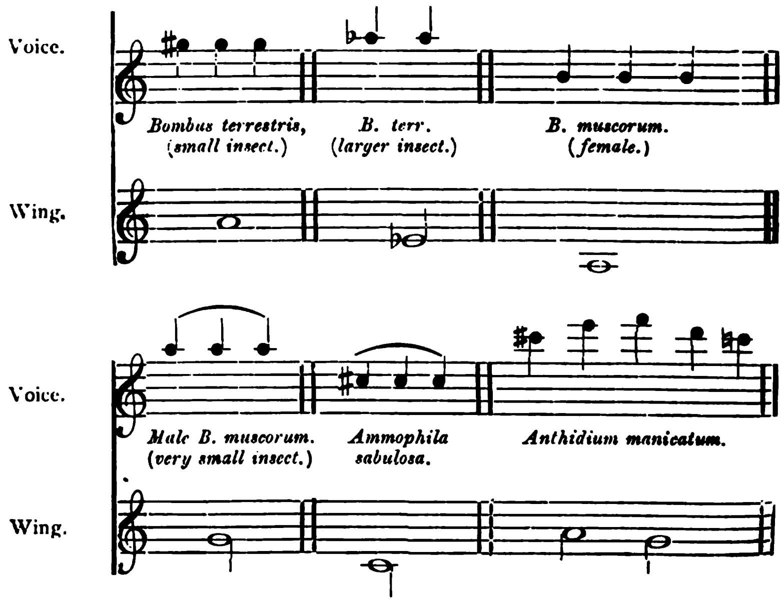


Voice and Wing-tone of Flies, Gnats, &c.

Voice and Wing-tone of Flies, Gnats, &c.



Bees.



4, *Pitch of the insect note.*

Many insects possess only one tone which is produced by the motion of their wings; other insects have a voice but their flight is silent. A third group possesses both flight-tone and voice, as *e.g.* the flies and bees.

The voice of most insects is different from the flight tone. The difference being mostly that of a few intervals, but often very much more. The flight tone of the honey bee is a' its voice is an octave higher, and often rising to h'' flat and c'''. Again which the common fly hums with its wings in f' its voice sounds h' and c''. The difference of tone is very great in the *Anthidium manicalum,* its flight tone being g' and its voice tone f''' nearly two octaves higher.

The flight tone is for the most part tolerably constant as it varies only by sinking, when exhaustion compels the insect to lessen the rapidity of its wing movement. The insect voice is, however, capable of a real modulation both in pitch and intensity. In fact a distinct melody may be recognised in the sounds of some insects. The common blue bottle buzzes the tones d'' sharp, d'' natural, c'', sliding down or up with the finest intertones, and after a short pause repeating the same sequence. A hovering fly (*Syrphus ribesii*) utters the notes e'' and d'' sharp, running them into each other at short intervals. The *anthidium* before mentioned exhibits the greatest compass of any insect examined by Dr. Landois, and it hums the notes c''' c''' sharp, d''' e''' f''' with numerous changes.

Friction tones as before remarked, rise or sink in pitch according to the fineness of the toothed or notched organ, and the rapidity of the bow stroke, *e.g.* the *cerambyx moschatus,* whose normal note is d'''' can produce a higher or lower note by quicker or slower friction movement,

The modulation of the insect voice may be attributed, firstly, to the varying number of vocal tongues set in motion, secondly, to their different length and state of tension into which they can be

brought by muscular action. Another circumstance which must affect the change of note is the probable change of current of air drawn into the body or forced out of it. It is well known that a tongue of metal set in vibration by holding the frame in which it is set, close to the lips, gives a different note, when air is drawn into the mouth, from that which is produced by blowing outwards. A difference of a half note is frequently observed.

Difference of sex of insect affects the voice only in so far as the voice apparatus is larger or smaller. Being for the most part larger in the female insect, the male voice is mostly higher in pitch !

5. *The mechanism of vocal sounds.*

The instruments we employ to produce musical sounds, are principally organ pipes (open and stopped as in diapason, flute, &c.) reed pipes (clarinet, oboe, &c.) bells, bars, strings, tuning forks, &c. The insect voice apparatus may be compared with reed pipes in their action, since a membrane is set in free vibration at the end, or near to the open mouth of the breathing tube. This breathing tube (trachea) represents a pipe which ramifies in a wonderful series of branching twigs distributed throughout the interior of the insect body. The terminal trunks of this tree open upon the surface of the body by mouths (stigmata) which may be seen on each side of the Thorax and Abdomen. The larger trunks within the body are connected by transverse tubes and in many insects larger expansions of the tracheæ are found which constitute a special apparatus enabling the insect to store a relatively large volume of air which it can force by muscle pressure through the vocal organ. Thus for instance in the "blue bottle" fly there are found two large tracheal sacs or bladders occupying a space in the back of the body which act as bellows. Before the tracheal tube reaches the locality of the vocal apparatus, it contracts somewhat in dimension; a vocal apparatus is only observed in the *thoracic* tracheal tubes.

The reed or tongue (vocal apparatus) is represented by minute

and thin chitinous membranes whether present in the form of curtain or leaf or in semi-cylinder. The state of tension in which these membranes are maintained by the action of muscle fibres attached to them exerts an essential influence upon the tones produced.

The *expired* air sets these membranes or elastic bands in vibration. Prof. Landois says that by cutting off all external organs of motion (legs, wings, &c) of a blue bottle or of *eristalis*, and laying the insect on its back on the surface of water, its trunk jerks forward with every utterance of sound. It is therefore by compression of air through the vocal apparatus affected by the movement of the trunk that sound is produced. If the vocal apparatus be sealed up, the trunk movement ceases. Professor Landois does not think that inspiration of air causes any sound. How does the air gain entrance into the insect's body? The extremity of the tracheal tube behind each stigma is supplied with a lever apparatus which when acted upon by muscles presses on the tube and narrows its calibre. By this arrangement the insect can at will open or shut the passage of entrance. At inspiration, entrance is made free and air passes into the body, but the tracheal tubes cannot in consequence of their inner chitinous lining membrane, propel this air further. Therefore the closing apparatus is worked, the muscles of respiration contract, and thus the air is driven on through the bronchial tree, to its finest ramification, and to the respiratory cells at their ends. If there were no apparatus to close the tracheæ, the air would simply pass outwards without being of any service to the internal functions of the insect's body. But by this apparatus the insect can regulate the quantity of air which it requires to take in. Thus when it wants to fly, it can fill its air tubes full, by inspiring quickly and not allowing the air to escape, and so pump air into its reservoirs; thus filling its bellows, so to speak, with air wherewith to utter sounds while it flies. As the principal stigmata are always situate on the insect's thorax, the contractions of the muscles of

this part in which the tracheæ are so minutely distributed, exert great influence upon the sounds produced. The vocal bands do not always require to be set singing by air expired through the apparatus; for the tone depends upon the quantity of air, and the rapidity of its motion, and upon the tension of the elastic ring in which the vocal bands are stretched.

The other insect sounds are more simply produced. The wing tone of many insects, flies, bees, and beetles—is due to rapid vibration of wings. In other cases as in crickets, grasshoppers, locusts and some water beetles, the wing covers are set in vibration by friction of notched ribs on the wing covers. In others again different parts of the body are provided with rasp edges and borders, as with the goat beetles, dung beetles, burying beetles, also the bees, ants, &c. Occasionally special resounding apparatus is met with, as in the case of the arched thoracic ring of the goat beetle, which vibrates powerfully with the underlying tracheæ, and in other cases the wing covers (of the cricket for instance) the abdomen or even the whole external chitinous skin, as may be felt when holding a fly between the fingers.

6. *Muscle action* in production of sounds.

In all rasping sounds the movement of limbs necessary to set wing cases in vibration, must be considered voluntary. In the special vocal stigmata of insects so provided, muscles and nerves may be found. In the flies the vocal ring and the edges of the valves are acted upon by muscles. The vocal ring is capable of a double movement, it can be drawn out in the vertical direction by muscle effort and retracted again by the elastic power of the ring itself. The effect of this movement is that the vocal ring which carries the vocal membrane may be lengthened and the edges of the vocal membranes thereby approximated, narrowing the chink between them, whilst at the same time they are tightened. Prof. Landois observed this action in an insect dissected and placed under the microscope. The sound issued whenever the muscle acted, and ceased when the vocal ring and its rings were relaxed.

In the bees the muscular action is not directly applied to the vibratory organ. The modulation of voice depends here wholly upon increased respiratory efforts. The vocal membranes of bees, drones, hornets, wasps, &c., are immoveably fixed behind the opening of the stigma. But over the vocal membrane, there is a cup or bell shaped cover of chitinous structure, in the middle of which a fissure opens towards the tracheæ. Here at this chink, or fissure, an arrangement for closing it is applied consisting of two small projections of chitinised substance which are connected together at their apices by a muscle band. When this muscle contracts the fissure is closed and no air can pass from the tracheæ into the vocal cavity. If the insect opens this fissure the air immediately streams out and sets the chords in vibration. This act must be therefore voluntary, and the bee can set its vocal apparatus in action when flying or at rest.

Reports of Meetings.

GENERAL.

JAN 4th, 1877.—Mr. B. Lobb gave a lecture entitled "A summer sojourn on the banks of the River Dart, near Holme Chase."

February 1st.—Mr. J. G. Grenfell read a paper on "Supersaturated Saline Solutions," the text of which appears above.

March 1st.—Dr. H. Fripp gave a lecture entitled "Notes on Insect Anatomy," illustrated with numerous diagrams. The part relating to sounds emitted by Insects appears above.

April 5th.—Mr. W. W. Stoddart exhibited samples of borings of different depths, which he had just presented to the Museum, and further explained the "Geological Section in Old Market Street:" the details appeared in our last Part. He next read a paper "On the Bergamot," exhibiting specimens in spirit. These are rather difficult to obtain. Mr. S. H. Swayne, M.R.C.S., gave a short account of a specimen of the Eagle Ray just added to the Museum. This appears above.

The summer Excursion was to the neighbourhood of Painswick. No report has reached us.

October 4th.—Mr. W. L. Carpenter read a paper on the "Articulating Telephone," which was illustrated with experiments. The text appears above.

Nov. 1st.—Mr. E. Wethered read a paper on the "Formation of Coal," an abridgement of which appears above.

December 6th.—Mr. Stoddart read a paper "On the occurrence of fossil bones of Water-vole in a fissure at Hotwells."—Mr. S. P. Thompson gave a short lecture on "Plateau's Cohesion Films," exhibiting experiments.

BOTANICAL SECTION.

DURING the last summer the Members of this Section have had the advantage of accompanying their President, A. Leipner, Esq., in the botanical excursions which he has taken with his students. The winter session has been spent in arranging the Herbarium, and incorporating with it the various additions that have been made.

W. HARGRAVE, M.A. Lond.,
Hon. Sec.

ENTOMOLOGICAL SECTION.

OWING to the extraordinary dearth of insect life during 1877, very little out-door work was accomplished by the Section. Only two out-door excursions were taken, and in both cases nothing of importance was captured.

A large number of interesting species was exhibited at meetings of the Section during the year by different members, among them being bred specimens of *Acidalia degeneraria*, and *A. contiguaria*, *Endorea phaeoleucalis*. captured at Portland: *E. grandaevana*, taken among coltsfoot on the banks of the Swale by Mr. Hudd; and numerous others.

At the December meeting the Hon. Sec. exhibited, on behalf of Mr. Mayes, a singular variety of *Orthosia suspecta*, the usual ground color of the insect being replaced by white, another specimen captured at the same time and place being the ordinary northern form of this species. This is the only recorded occurrence of this species in the Bristol district.

At the December meeting the Chairman of the Section, Mr. Barton, made some interesting remarks upon the use of the Antennæ of insects, showing that the commonly accepted view, that they are used simply as feelers, was

in many cases almost an impossibility. It appeared more probable that the antennæ were used for a combination of the senses, more especially hearing and feeling, in some species hearing being most predominant, and in others touch. Mr. Barton exhibited some interesting species of the genus *Paussus* as illustrating the former, and mentioned the Cerambycidæ as well illustrating the latter, while different species of weevils were well illustrative of both senses combined, the slightest noise having the same effect as a touch upon them.

At several meetings of the Section attention was drawn by several members to the extraordinary abundance of *Colias edusa*, which has swarmed to an extent never before recorded in England, having been by far our commonest butterfly through all the southern and eastern counties, the general scarcity of other species making it the more remarkable.

GEO. HARDING, *Hon. Sec.*

GEOLOGICAL SECTION.

1877.—February 22.—Annual Meeting. Mr. Stoddart gave an account of the strata passed through in sinking a well in Old Market Street, Bristol, to a depth of 300 feet.—Officers re-elected.

Mar. 22.—Meeting. Mr. Stoddart read a paper on the Foraminifera found in the Clifton Rocks, and illustrated it with microscopic preparations.

Walks were taken during the summer months.—Easter Monday, April 2, to East Harptree, to examine the Harptree Chert.—May 31, to Weston-super-Mare and Woodspring, where the raised beach and the igneous rocks were examined, and the party were very hospitably entertained by Mr. Whidborne.—June 16, under the Clifton Rocks to Sea Mills.—July 3, to Holwell, where the Rhætic fissures in the Carboniferous Limestone were examined, one fissure containing Post-tertiary remains.—September 20, to Portishead, where the Carboniferous Limestone and Old Red Sandstone were examined. The limestone quarry above the church has an unusual appearance, the fossils appearing in bends in the centre of certain beds, and in a silicified state sometimes. Some of the members considered it to belong to the New Red, and that the fossils were re-deposited. All the facts, however, are against this view. Mr. S. Derham found *Helodus lævissimus*, and presented it to the Museum.

A. C. PASS, *Hon. Sec.*

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NEW SERIES, VOL. III., PART I.

Some New Optical Illusions.[1]

By SYLVANUS P. THOMPSON, B.A., D.Sc., F.R.A.S.,

(Professor of Experimental Physics, University College, Bristol.)

IN the Transactions of various learned bodies—the Royal Society, the British Association, &c.—papers have appeared from time to time describing various Optical Illusions. Some of these illusions have depended upon the duration of retinal impressions, some upon the formation of accidental subjective images, some upon the dispersion or irradiation of the eye, and some upon the phenomena of binocular vision. The illusions to be described in the present paper do not fall exclusively under any one of the heads enumerated, though they depend upon the duration of visual impressions, and upon a further and less perfectly understood property of the retina. They are all dependent upon *motion*, either of the object or of the observer, or of both. In each case that will be here brought forward there is a movement of the object across the field of view, and consequently of the image across some portion of the retina.

The most frequent illusions which arise thus are those in which one form of motion apparently takes some other form. As a most familiar instance of this kind of illusion we may take the case of the apparent motion of trees, hedgerows, and houses, as seen from a rapidly-running railway-train, the deception of the senses being most complete when the personal sense of motion is least.

[1] The greater part of this article was read before the British Association, at Plymouth, in September, 1877, an abstract only having as yet been published. A few additional facts were recently communicated to the Bristol Naturalists' Society, and are embodied herewith.—S.P.T.

When the train in which you are seated is drawn up beside another train, and then moves slowly forward, smoothly and without jolting, it is extremely difficult to tell whether your own train or the other one is in motion.

So when light clouds are drifted across the moon, one can frequently hardly resist the notion that it is the moon that is sailing along amongst fixed clouds; and if the drifting of the clouds be due to an upper current, while the lower air is still, the impression that the moon is sailing along past the clouds asserts itself with remarkable force.

I have observed an illusion closely akin to this at Clifton. Underneath the famous Suspension Bridge, a zigzag path winds up to the top of the cliff, shaded overhead by trees. Walking up this path you see the bridge at intervals between the boughs, and, as the body rises and falls with the motion of each step, the bridge appears to be swaying violently up and down, as if it were blown about in the wind.

Many illusions akin to these very simple phenomena have been recorded from time to time. Three times—in 1845, 1848, and 1861—the late Sir David Brewster drew the attention of the British Association to some phenomena seen in railway travelling. If from the window of the carriage you look out at the pebbles and stones lying beside the line, you catch merely vague strips, due to the rapid motion of their images across the retina; but on suddenly shutting the eyes "a motion is perceived in a direction transverse to the real impressions on the retina; and there is the appearance of lines complementary in the same transverse direction."[1] This Sir David subsequently referred to a subjective opposite motion going on simultaneously, and so causing a compensation of the impressions moving on the retina. In 1861 he returned to the observation, and compared the phenomenon with that obtained by watching the motion of a rotating disk with

[1] Brit. Asso. Report, 1845.

radial markings, directing the eye first to a point near the circumference, and then afterwards to a point near the centre, where the motion was slower. He concluded that there was a neutral line across the retina at which the compensation of the subjective impression was complete.

In the "Philosophical Magazine" for 1834 (p. 373) R. Addams described a peculiar optical phenomenon. After looking for some time at a waterfall, and then at "the sombre water-worn rocks immediately contiguous," he "saw the rocky surface as if in motion upwards with an apparent velocity equal to that of the descending water." This he ascribed to an unconscious recurrent movement of the muscles of the eye-ball, continuing after the gaze had been directed to the rocks, and thus occasioning a displacement of the images on the retina.[1]

This illusion becomes more remarkable in the slightly varying case now to be mentioned. Watch the water of a rapid river, such as the Rhine immediately above Schaffhausen. The middle stream is running forward very rapidly. After watching it fixedly for some time, transfer your gaze to the slower stream near either bank. It actually seems to be running back.

I have also noticed, after watching a procession, that stationary objects appeared for a moment to be moving in a contrary direction.

In the "Journal of the Royal Institution, (vol. i., p. 609) an anonymous writer records a curious observation, that from a slowly-moving railway-train, while the stones and sleepers beside the line appear to fly back past the train, the neighbouring set of rails seems to be flying forward and keeping pace with the train. This he refers, and doubtless rightly, to the fact that the rails are

[1] An account of a very similar observation was communicated by Mr. J. Aitkin to the Royal Society of Edinburgh, in November, 1878, apparently without any knowledge of the observations of Addams, Brewster, or of the author of this article.

of nearly uniform tint, and destitute of markings that would produce upon the retina impressions like those of the adjacent objects.

The railway affords many other instances of optical deception, and of these I will mention a few of which I am not aware that any specific notice has hitherto been taken.

When a landscape is observed from a moving railway-train, all distant objects from the near hedgerows to the distant hills appear to be moving past in the opposite direction, the nearer objects having the greater apparent velocity. Consequently, if the attention be fixed upon any object at some distance from the line, all objects beyond will relatively appear to be moving forward with the train, while objects nearer appear to be moving backwards. The combined effect is to make the entire landscape appear to be *revolving centrally* round whatever point we fix out attention upon.

Falling rain seen from a moving train always seems to fall obliquely (except in a *very* strong gale in the direction of the train's motion) in a direction opposite to that of the motion of the train. But if another train happen to pass in an opposite direction, and we look out at this and follow it with our eyes, rain-drops falling between the two trains will seem to be flying forward with ourselves.

If we stand on the platform of a station and watch a train approach, the end of the engine appears to enlarge or swell up as it approaches and occupies a larger area of the field of vision. Conversely the end of the last carriage of a retreating train appears to shrink down and contract as it diminishes in apparent magnitude. Stationary objects by the side of the line similarly appear to swell up as we approach them in a train, and to shrink together as we retreat from them. Curiously enough, this motion is also one which calls forth a certain "compensation" in the action of the retina. For, suppose we have been watching objects enlarging as we approached them, and then suddenly transfer our gaze to the side of the carriage opposite to us, we

shall observe that it is apparently shrinking together and retreating from us. The opposite effect—that of apparent enlargement and approach—is produced as a subjective compensative action after watching objects from which we are retreating. The effect is more amusing if, after observing either of these cases of motion, we transfer our gaze to the face of a fellow passenger sitting opposite.

An observer at some slight elevation above a railway, seeing two trains pass along the lines simultaneously in opposite directions, will receive the impression as of one long train moving round a circle. For when you look at a revolving wheel nearly edgewise, the nearer edge is seen moving past the farther edge, and in an opposite direction. The apparent motion of the two trains is the converse of this impression.

If from a similar situation two trains are observed, one moving rapidly, the other slowly in the same direction, the slower train may appear indeed to be moving in an opposite direction—a phenomenon similar to that of the Rhine above Schaffhausen already noticed.

Dr. F. Guthrie has noted the following illusion :—Looking at the arms of a windmill in motion, in the twilight, or at such a distance that their attachment to the mill is obscure, we can, when the aspect is very oblique, easily imagine the arms to be turning in the opposite direction. We then fancy we are looking at the other side of the mill : so that if the sails are actually towards us in their descent, we fancy them away from us in their descent, which gives the notion of rotation in the opposite direction. This hallucination can, after a little practice, be as readily controlled by the will as can the introversion of a linear drawing representing a solid."[1]

An analogous illusion is produced by illuminating certain vacuum-tubes with the sparks of induced electricity discharged

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[1] GUTHRIE, Magnetism and Electricity, p. 243.

alternately in opposite directions,[1] when the tube appears to be rotating about an axis perpendicular to its length and to the line of vision.

A crow flying along at dusk, seen against the sky at a low altitude, shows, when passing the observer, his wing above and beneath his body alternately. The effect of this alternation is as if he had but one wing, which seems to revolve round like the blade of a screw-propeller about its axis.

I have frequently stood upon the lofty suspension-bridge over the Avon, at Clifton, when large ships have been passing beneath. Under these conditions a curious illusion may be observed. If you look perpendicularly down on to a ship, as it emerges from beneath, it appears to be heeling forward on to its bows; for as the masts emerge from under the bridge, and you see them growing longer as the fore-shortening effect passes off, the mind cannot resist the notion that—like the windmill-sails—they are revolving round a centre. I have pointed out this effect to several persons, who have expressed much surprise at the completeness of the illusion.

The last set of illusions which will be described took their origin in an observation made by the writer early in 1876. He had been drawing a series of concentric circles in black and white, for the purpose of testing the astigmatic conditions of the eye. Happening to shake the paper upon which the diagram was drawn, he observed a peculiar motion of apparent rotation of the circles. This illusion is extremely curious, and very easily reproduced. Let concentric circles in black and white be described upon a piece of card *(Pl. I., fig. 1)*. If this be held firmly between the thumb and finger of the hand, and then a slight but rapid circular shaking motion be imparted by the wrist and elbow, the circles will appear to rotate upon the card. The hallucination succeeds

[1] See S. P. THOMPSON in Phil. Mag., 1876.

Plate 1.

Fig. 1

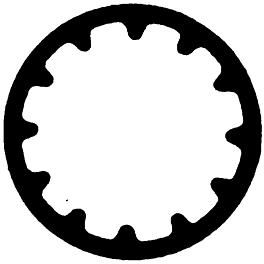


Fig. 2.

Fig. 3.

best if the circles be clear and sharp at their edges, and the successive rings of black and white of equal widths. Their number and width is immaterial, but there seems to be a particular distance from the eye for each width of successive rings, at which the illusion succeeds best. Finely-drawn narrow rings must be held near, to produce a maximum effect; while to enable a number of persons to see the illusion at once the rings may be half or three-quarters of an inch in width, and to the number of fifteen or twenty. The radius of the circle of imparted motion should equal the width of a black or of a white ring, and the rapidity found most successful is that when each rotation occupies from one-sixth to one-fourth of a second. The rings appear to rotate once for every complete motion of the hand and card in the circular path, and in the same direction as the imparted motion. In this experiment each ring is displaced to a distance equal to its own breadth in every direction successively around its centre; and as the impression remains a short time on the retina, the optical effect is equivalent to that of a ring eccentric to an equal amount and actually rotating. Hence the illusion.

I have constructed a large number of patterns of curvilinear, circular, elliptical, eccentric, and concentric lines, many of which exhibit, in whole or in part, the same phenomena of apparent rotation. One of these *(Pl. I., fig. 2)* is a single black circle, having a number of internal cog-teeth, upon a white ground. This circle, when shaken circularly in the manner described, appears to move round in the opposite direction to the imparted motion, and to move round through a distance of but one tooth for each successive complete motion. For circles possessing this property I have suggested the name of "Strobic Circles." Their motions are best seen when the eye is directed not exactly at the circles, but at some point near them. I have therefore found it more effective to have two strobic circles, drawn side by side upon one card. That circle rotates most obviously on which the gaze is *not* fixed.

Further, I have noticed that if a strobic circle be "rotated," while a number of other circles are lying stationary within the field of view, when the eye was directed to the moving circle the others also began to "rotate" *(Plate I., fig. 3)*.

This last observation cannot, I think, be explained on any supposition of unconscious muscular movement. In fact I entirely doubt the validity of this hypothesis in the case of Addams's observation upon the waterfall before cited.

I am inclined rather to attribute these effects, and those of "compensation" in general, to waves of nervous disturbance moving over the retina; these waves, being of two orders,—one primary, and in the same direction as the objective motion of the images upon the retina; the other secondary and later in time,—giving rise to the subjective motions of compensation. I do not see how on any other supposition the phenomena noted in an earlier paragraph relative to compensative shrinking or expanding of objects can be explained. Such a hypothesis, will, I believe, also embrace all the other phenomena of apparent motion, except those which are the result of mental associations alone—such illusions, in fact, as those of the windmill and the flying crow. Such waves of nervous disturbance have, it would seem, a definite rate of propagation, probably not independent of the nature of the moving image with respect to colour, relative luminosity, and apparent magnitude. But whether these waves of sensible impression are due to a physical motion of any structures of the retina I am not yet prepared to offer an opinion.

Underground Temperature.

BY E. WETHERED, F.C.S., F.G.S.

GEOLOGY and Chemistry have revealed to us a mass of information concerning the nature and composition of the crust of our earth, but how far that crust extends, and what it encloses, is even at the present day a matter of considerable doubt.

The inconsistency between the known specific gravity of the rocks which compose the crust of the earth, and what would be the specific gravity of a similar solid globe, renders it clear, that the earth is not a solid, or, that there must be a nucleus, composed of a substance, or substances, of a much less density than those which compose the crust.

With a view of gaining information on this matter, we naturally turn to volcanoes, hot springs and geysers; these phenomena all indicate the presence of heat. But if we agree thus far, we may not concur as to the direct cause or source of this heat: are we to consider that the water of springs and geysers derives its heat from chemical action within the crust of the earth, or from the substances contained in the water, or is that heat derived from a lower region?

With regard to the first,—chemical action within the crust of the earth, Professor John A. Church, of Ohio, North America, recently contributed a paper at the Chetauooga Meeting of the American Institute of Mining Engineers on the "Heat of the Comstock Mines;" he states that the rocks in the lowest levels of the mines appear to have a pretty uniform temperature of 130° F.

The source of this heat is attributed to chemical action now maintained in the eruptive rocks. But it is remarkable that the heated rocks occur only in belts with cold masses between them.

Professor John A. Church[1] supposes the existence of a cold, and what may be termed a burnt-out layer of rocks, extending for 1000 feet below the surface, and a zone of hot rock still in active decomposition, which has been found to exist for a depth of about 1500 feet more, and no doubt, he thinks, extends thousands of feet further, and finally, a mass of cold rock at a great depth, which has not yet begun to decompose. The author also refers to one of the hottest belts, being a quartz seam, which appears to be entirely in the dorite; and though he attributes the heat to chemical action in the eruptive rocks, he states that it is not a combustion, for the oxidizable constituents are little altered. Now it is difficult to imagine chemical decomposition going on in any rocks without the oxidizable minerals being affected, especially at a temperature of 130° F.

It would be rash to express any decided opinion on the source of the great heat in the Comstock mines, from simply reading the paper referred to, but the fact of the oxidizable minerals not being affected seems to me to be a strong argument against Prof. A. Church's theory.

The fact of a quartz vein in the dorite being one of the hottest parts suggests another supposition, namely, may not the hot belts be fissures, through which hot water was, at one time, ejected, but which, in course of time, have been closed up, chiefly with silica deposited by the water, but through which heat may still be transmitted from below. As an instance of this, I may mention the "Great Geyser," which has deposited silica several feet thick in a crevice.

With regard to thermal springs and geysers, it is difficult to understand the temperature being maintained by chemical action

[1] Monthly Journal of Science, March, 1879, p. 224.

generated, either by the constituents contained in the water, or transmitted by the chemical decomposition of the environing strata, because of the high temperature to which the water sometimes attains, and its continuance for such long periods as are known. Salt and mineral waters have a slightly higher temperature than fresh, but from the experiments of Dr. Gustav Bischof[1] it would appear that the addition of such salts as these waters contain, causes a very slight increase in temperature. He says: "The Heilbronn, a mineral spring in a small valley of the Brohl, four miles distant from the Lake of Laach, is next to Bilui, near Bohemia, the richest in carbonate of soda known to me. It contains 0·0053 of fixed substances. Suppose that this spring were formed from anhydrous carbonate of soda by the addition of concentrated sulphuric and muriatic acids and water, then according to my analysis 77·4 parts anhydrous carbonate of soda, 5 parts of concentrated sulphuric acid, 92 of smoking muriatic acid, and 22·687 parts of water would be required to compose a water containing the same proportions of carbonate and sulphate of soda and of chloride of sodium as that spring. In accordance with this, therefore, I put 77·4 grains of calcined carbonate of soda to 22·687 grains of water. The temperature of the water was—

Before the experiment - - -	42°·8
After - - - - - -	43°·7
Increase of Temp.	0·9

To this solution of soda I added a mixture of 5 grains of concentrated sulphuric acid, and 92 grains of smoking muriatic acid. The temperature of the two liquids was —

Before the mixture - - -	50°·00
After - - - - -	50°·45
Increase of Temp. -	0·45

[1] Physical, Chemical, and Geological Researches on the Internal Heat of the Globe, p. 16.

"Now, although such a chemical process as this, which is very improbable to take place in the interior of the earth, is the most favourable for the production of heat, still it only caused an increase of temperature of 1°·35." We can, therefore, only attribute the temperature of thermal springs aud geysers to the superior temperature of the interior of the earth. Volcanic action is a strong argument in support of this view. The enormous quantity of molten matter thrown out from their craters tells of a heat below, such as would fuse any substance known. But as some substances are less fusible than others, it seems reasonable to suppose, that there is no hard and fast line between the solid and the fused, but that the former merges into the latter.

To solve the problem of underground temperature, resort has been made to mines, bore-holes, and wells; and from results obtained, the datum adopted by the Royal Coal Commission was, 1° increase for every 60 feet in descent, but I cannot but think, after reviewing many observations made, that there is not sufficient evidence to warrant the assertion as a fixed datum for calculation.

In 1867 the British Association appointed a committee to investigate this subject, and Prof. Everitt, the able secretary, has annually produced valuable reports. When this committee first entered upon the field, they had not only to find places for observations, but to devise a method, which could only be arrived at by experience. To the ordinary reader it may appear a very simple thing, but I can assure you there is scarcely any scientific work which requires greater care and thought.

The sinking of shafts has been looked upon as giving exceptional facilities for observation. The usual method has been to bore a hole in the strata two or three feet deep, at regular distances, say 50 feet. The hole is bored with an ordinary borer, then filled with water, and the thermometer inserted. The time which the instrument has been allowed to remain in has ranged from half-an-hour to several hours. Observations thus made, would appear at

first sight, to give the most reliable results, and possibly some good ones may have been so obtained. But it frequently happens that a considerable amount of water flows down the sides of the shaft from springs cut through during the sinking, and varying in temperature: this water then, must have some effect on the strata at the bottom of the shaft; and to obtain accurate observations under such conditions is difficult, and may perhaps account for the discrepancy in results so obtained.

Then again, old shafts, partly filled with water, have been utilized for observations, it being assumed that the column of water would attain the temperature of the earth, but these, I consider, to be open to great objection, owing to the inflow of water of various temperatures (termed convection), which, in some instances, would vary with the seasons. A good illustration of this is shown in the observations made by Mr. David Burns, H.M. Geol. Survey, in a shaft at Allandale, near Carlisle. The shaft was over 50 fathoms deep, and was about half-full of water. The result was as follows:

i. *After a period of drought.*

Depth,	160 feet.	Temperature,	47°·5
„	200 „	„	47°·0
„	250 „	„	47°·7
„	300 „	„	47°·7

ii. *Shortly after heavy rain.*

Depth,	160 feet.	Temperature,	47°
„	200 „	„	47°·5
„	250 „	„	47°·3
„	300 „	„	47°·3

Another discrepancy, which I think may be ascribed to the same cause, was in the case of a well at Kentish Town where, for the depth of 210 feet, a second series of observations gave an excess above the first of from 2° to 5°.

Observations have also been made in deep bore-holes, but these offer two objections, viz.: convection, and the time it takes to raise the thermometer. The latter difficulty, however, has, to a great extent, been overcome by the construction of slow-acting thermometers, but the former has not as yet been satisfactorily dealt with.

In the Quarterly Journal of Science, for January, 1868, Mr. Hull, F.G.S., points out the necessity of observations at low depths, and suggests the idea of starting a bore-hole within the workings of a mine. I need hardly say, that if such could be accomplished, most reliable results could be obtained, but such opportunities do not often present themselves. A few observations have been made within the workings of mines, but objection has been taken on the ground, that the results would be affected by the air-currents, by the heat of the lamps, by the bodies of the colliers and horses. Doubtless where the thermometers cannot be isolated from these influences, little reliance could be placed in the results. In mines where explosive gas is generated, it might be impossible to isolate the thermometer from a brisk air-current, but, as in the case of our own coalfields, where the majority of coal-seams do not yield explosive gas, this difficulty may often be got over.

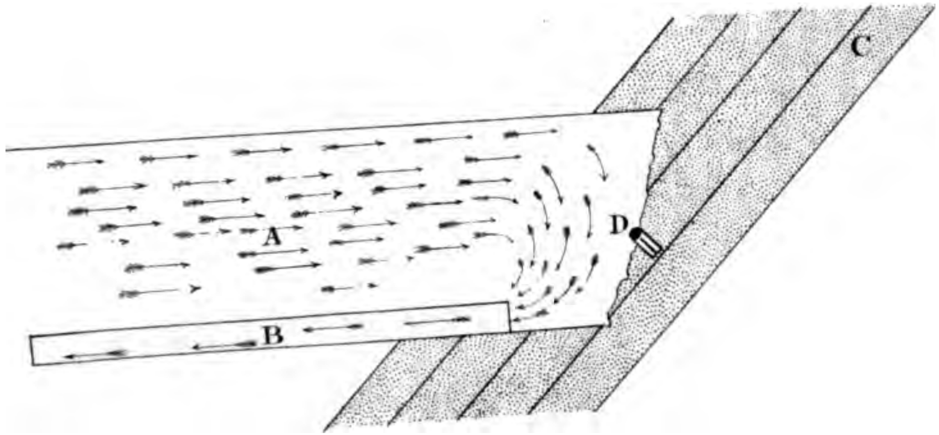
Last year (1878) Prof. Everitt sent me one of Negretti & Zambra's patent mining thermometers, for observations in the workings of the Kingswood Collieries, near this city. The way in which I proceeded was as follows:—observations were made only in new ground, and the thermometer was inserted on the day on which the strata were exposed: for this reason, cross measure branches and advanced levels were selected as the places for operation. The thermometer was placed in a hole 2 feet deep, and the mouth was tightly closed with clay rolled in the form of a plug.

The following is the method of which I was able to avail myself:

The branch A is driven in the solid rock; the air enters as indicated by the arrows, and returns through the trunks B. If, therefore, the mouth of the trunks is removed a few feet back

SECTION

of a Cross Measure Branch, Showing Temporary Ventilation. and Thermometer inserted.



Jefferies Lith Bristol.

rom the face of the strata, of course the bulk of the air will not each it, and it is therefore possible to protect the hole D, in which the thermometer is placed, from its effect, and when we emember that the top of the hole is tightly plugged with clay, here is not much chance of the instrument being affected. Some ery satisfactory readings were taken in a branch of this description, t a depth of 1439 feet in the Speedwell Pit workings, the details re as follows :—

On Saturday, August 17th, 1878, the thermometer was placed n hard arenaceous rock, for the usual time (Saturday, 2 p.m. till Monday morning early), when 69°·7 F. was read : the reading was onfirmed on the following Saturday till Monday. In the October ollowing, a seam of coal was cut, known as the "Two feet," and n observation in this, and one in the strata upon which the coal ests, gave the same : so that I think there can be no doubt as to 9° 7 F. being the correct temperature for that depth. The next oint was to ascertain the temperature at the surface, so as to get t the rate of increase. Various measures have been suggested, uch as observations in wells, at stated periods, extending over, at east, twelve months, or selecting depths near the surface, so as to etermine where the constant temperature begins. I think the ormer process is very liable to error, for two reasons—1st. Wells re very apt to contain organic matter, derived from the decay of ead leaves, and too often from various other organic contamin- ions, and by this decomposition, heat must be generated. 2nd. n deep wells, which alone would be serviceable, water, of different mperatures, might flow in, especially after a wet period.

Observations have been made in various places to determine the fference between the temperature of the earth a few feet down, and e mean temperature of the air on the surface. The result at 3ft. low the surface, at three stations established in Edinburgh by of. Forbes, gave, after five years' observations, an excess of 0.55 ove the mean temperature of the air. In Paris, in the year 1825,

observations were made by sinking a thermometer in the earth, and it was found that the influence of external heat did not extend below 25 feet. Prof. Everitt in some of his calculations, assumes that the surface of the earth has a temperature of 1° F. higher than that of the atmosphere. D'Aubuisson has put the depth, not affected by solar heat, at between 46 and 61 ft., and Kupuff at 77.

For my own observations, I preferred to take the mean annual temperature (48·7 F.) of the atmosphere as given by Dr. Burder, of Clifton, the results of 16 years' observations. They were taken in latitude 51°·27′ 49″ N. Longtitude, 2° 36′ 30″, and 192ft. above the sea level. The point on the surface, which is about the centre of the Kingswood workings, is just 3½ miles distant in a straight line.

Adopting then 48°·7 as the surface of datum, the following will be the tabulated result of my observations, arranged in order of depth, and carried out after the method above described:—[1]

Depth in feet.	Temperature, Fathrenheit.
402	48 7
1232	54·7
1367	66·7
1439	68·5
1769	74·7

Comparing each depth with the next, we have the following results:—

First, 402 feet	1° for 67 feet.
Next, 830 "	1° " 69 "
Next, 135 "	1° " 75 "
Next, 72 "	1° " 75 "
Next, 330 "	1° " 66 "

The average, from the surface down to depth 1769 feet, is 1°F.

[1] For details of the observations see report of the Underground Temperatures Committee.—*Report of the British Association*, 1879.

in every 68 feet, or comparing the depth, 402 feet, with the lowest 1° in 68·35 feet.

All the observations made on behalf of the British Association Committee show an increase downwards, but the rate varies considerably, as the following tables[1] will show. In their construction, I have extracted the chief results, taking the lowest depths as the most reliable. I do not wish to under-rate their value, in any way, but I have little faith in the majority of observations made in shafts, wells, or bore-holes, unless special precaution has been adopted to protect the thermometer against the influences before referred to. Indeed I question whether sufficient precaution is practicable.

OBSERVATIONS IN MINES.

	Surface Temp. F.	Greatest Depth.	Temp. Registered.	Feet per ° F., 1°.
Baldon Colliery, between Newcastle and Sunderland ...	48°	1514	79°	49
Fowler's Colliery, Pontypridd, South Wales	51°·5	846	62°·7	76
Kingswood Colliery, near Bristol	48°·7	1769	74°·7	68

OBSERVATIONS IN SINKING SHAFTS.

NAME OF SHAFT.	Surface Temp. F.	Greatest Depth.	Temp. Registered.	Feet per 1° F.
Rosebridge	49°	2445	94°	54·3
Dunkingfield, Cheshire ...	49°	1401	66½°	80

[1] The result given in the Tables by no means represents the whole of the work done by the British Association Underground Temperature Committee.

OBSERVATIONS IN SHAFTS OR WELLS.

NAME OF SHAFT OR WELL.	Surface Temp.	Greatest Depth in feet.	Temp. Read F.	Feet per 1° F.
Kentish Town Well, 1st series...	49°	1100	70°	52·4
" " " 2nd "	49°	1100	69°·7	55·6
W.B. Lead Mines, Northumberland—1st, Gin Hill Shaft ...	45°·3	400	51°·3	66·6
2nd, High Underground Engine Shaft	44°·3	807	65°·4	40
3rd, Slitty Mine...	44°·3	660	64°·9	33·5

OBSERVATIONS IN BORE-HOLES.

NAME OF BORE.	Surface Temp.	Greatest Depth.	Temp. Registered.	Feet per 1° F.
Blythswood		354	53°·6	
South Balgray, west from Glasgow		525	59°·3	41
Crawriggs, Kirkintilloch, near Glasgow	34°	350	51°·	75
Bore at bottom of South Hutton Colliery, Derby		1924	96°	
Winderley, near Lincoln, ...	50°	2000	79°	69
Booth Waterworks, Liverpool		750	56°	131
La Chapelle, Paris	53°·1	1950	75·4°	84

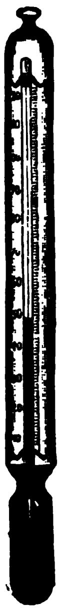


Fig. 3.

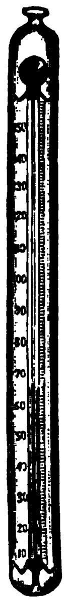


Fig. 4.

There are two thermometers now constructed especially for the committee by the firm of Negretti and Zambra. Fig. 3 is the slow action thermometer for taking direct earth temperatures. The bulb of this instrument is shown in its glass sheath surrounded by a good non-conducting substance, as suggested by Professor Everett. The thermometer is lowered down to the desired depth, in a copper case, and allowed to remain for a stated time (in the case of my observations for 48 hours.) It is then drawn up and the reading taken, but should the time occupied in raising the instrument exceed 4½, or at the most, 5 minutes, the reading would not, I think, be reliable.

Fig. 4 represents the maximum thermometer. The mercury bulb is at the top, and on the temperature rising, the mercury of course expands, and leaks out into the glass tube; on gently tapping or shaking the thermometer, it falls down to the column in the bottom of the tube: the height of the whole represents the temperature.[1] This thermometer is available for any maximum temperatures, and will not fail to give satisfaction; the same may be said of the slow acting minimum thermometer.

[1] I am indebted to Messrs. Negretti & Zambra, of Holborn Viaduct, for the use of the stereo of the thermometers.

The Structure and Life-history of a Sponge.

By Professor W. J. SOLLAS, M.A., F.R.S.E., F.G.S., &c.

The presentation of a tolerably complete account of any single species of sponge is a matter of considerable difficulty, since, notwithstanding the existence of many hundreds of species of sponge, which have been made known to us by excellent figures and descriptions, there is not one of which the complete life-history is known. That of which the history makes the nearest approach to completeness is the calcareous sponge, now known to naturalists under the name of *Sycandra raphanus*.

General Form.—This little sponge, not more than 3 or 4 mms. (*i.e.* $\frac{1}{5}$ of an inch) in height, presents us with a variety of forms, being sometimes spindle-shaped, sometimes ovate, at others, turnip-shaped, and occasionally almost spherical. Sometimes it is supported on a short stalk, and sometimes it has no stalk, or is sessile. Internally it is hollow, like a sac, the walls, or sides of the sac, being 2 mms. thick, and the internal cavity about 2 mms. across. The sac is closed below, but opens above by a circular or elliptical mouth, which is surrounded by a graceful fringe of slender needle-shaped spicules, composed like the rest of the spicules of the sponge, of carbonate of lime, and an organic substance known as 'spiculin.'

The spicules of the fringe, or corona, are sometimes seen in movement, now diverging from each other till they give to the corona the form of an inverted cone, and again approaching one

another to form a cylindrical tube. The surface of the sponge is covered all over by erectly projecting spicules, which render it hirsute.

General Movements.—With the exception of the movements of the spicules in the corona, the sponge gives very few signs of life, so that at first sight one might almost regard it, as indeed the older naturalists did regard it, as a plant. It is, however, in every respect, a true animal, lively enough in its way, and of wonderfully complex structure.

That it is not quite so inert as it seems may be easily shown by putting a little finely powdered indigo into the water in which a healthy specimen is confined. The particles of coloring matter will then be observed to make their way towards the general surface of the sponge, over which they spread themselves, and then disappear below it. After being lost to sight for a little while they re-appear, not over the surface where they went in, but streaming out of the central mouth in a powerful current. From this we may infer that minute currents are entering the sponge throughi ts general surface, passing through its walls into the central cavity, and then outwards by way of the mouth.

General Structure.—So far the sponge has been regarded simply as a hollow sac, but the walls of the sac possess a somewhat complicated structure, which we must now describe. Commencing from the inner face we find first a membranous lining, perforated by a great number of small holes, which are called mouths, or ostia, and because they open into the stomach, stomachal mouths or gastral ostia. Each is the open end of a thin-walled tube, which is closed and conical at the other end, and except that it is hexagonal in section, somewhat similar in form to a chemist's test-tube. These tubes radiate from the gastral ostia to the exterior of the sponge, and constitute, lying side by side, joined close together, the greate part of the sponge wall. By holding together a number of test-tubes, and supposing them to be joined along their lines of contact,

we shall gain a fair idea of this arrangement. Further, it will be seen that however close the test-tubes lie to one another, narrow three-sided canals will remain between them, one such canal between every three mutually adjacent tubes. Precisely similar canals are left between the tubes of the sponge, and are known as inter-canals, whilst the tubes themselves are termed radial tubes. The radial tubes have not continuous walls like those of a test-tube, but are perforated all over by a number of minute apertures, or pores. Those pores which occur over the projecting conical ends of the tubes open immediately to the surrounding water; those which occur along the sides of the tubes, where they are not in contact, open into inter-canals, and so indirectly into the outer water, while those finally, which occur along the line of union of the radial tubes serve as a means of communication between these tubes, and do not open into the outer water at all, except, of course, by way of the stomach through the mouth.

Histology.—The proper wall of the stomach, and alike of the radial tubes, consists of three layers of tissue, an outer, or ectoderm; an inner, or entoderm; and a middle, or mesoderm.

The *ectoderm*, which covers the stomach and the exterior of the radial tube lining the inter-canals, consists of a single layer of plate-like polygonal cells, 0·015 to 0·025 mm. in diameter. Each contains a circular cake-like nucleus, bounded by a nuclear membrane, and full of watery fluid, in which are suspended two or three very refractile granules, or nucleoli; the protoplasm in the centre of the cell, surrounding the nucleus, is more or less granular, but towards the margin perfectly clear.

The *mesoderm*, which succeeds, is of a very different nature, the great mass of it consists of a clear transparent jelly-like material, which does not stain with carmine or other colouring re-agents: dispersed through this jelly-like matrix are numerous cells of branching form. Each contains in the middle a long oval nucleus, with spherical nucleolus, and is surrounded by finely

granular protoplasm, from which are produced a number of fine irregularly branched filaments, which anastomose with similar filaments from similar adjacent cells. In general terms, therefore, this tissue may be said to consist of a network of protoplasmic cells immersed in a quantity of clear indifferent jelly: the jelly, in all probability, being derived from the contained cells by metamorphosis. Altogether the tissue most closely resembles the jelly-like tissue of the disc of the medusa, or jelly fish, and is also related to the embryonic connective tissue of the higher animals.

The matrix of the mesoderm serves as a medium for two other forms of cells, in addition to the stellate, or branched ones; in some parts of it, particularly in the neighbourhood of the gastral ostia, the stellate cells pass into others of a simpler form, by losing their branching processes, and becoming fusiform. The fusiform cells, so produced, are of considerable length, and lie in parallel bundles concentrically round the edges of the gastral ostia; and since they have the property of shortening in the long direction, and broadening in the transverse direction, under the influence of a stimulus, they serve as muscular sphincters to the ostia, closing them when irritated and opening them again on relapsing into their normal state. The third kind of cell found in this tissue is probably the least differentiated, and is possibly the parent form of the others, it is a little mass of protoplasm, containing a nucleus and nucleolus, and closely resembles an ordinary amœba, or nucleated blood corpuscle, thrusting out pseudopodia in various directions during life, and moving freely by their means through the surrounding medium.

The innermost layer, or *endoderm* forms a continuous lining to the inner wall of the radial tubes, meeting at the edges of the pores and gastral ostia, the outer layer of plate-like epithelium or ectoderm.[1] It consists of more or less flask-shaped cells, each

[1] I have followed Hackel in referring the lining membrane of the stomach

having a nearly spherical body, flattened below where it is seated on the inner face of the mesoderm, and rounded above and prolonged into a long neck or *collum*. Near its end the collum is surrounded by a delicate collar of transparent sarcode, which gives it the form of a wine glass. From the end of the collum is produced a long filament of hyaline protoplasm, known as the flagellum, because it flagellates the surrounding water.

The cell, in general, consists of a more fluid granular central protoplasm, or endosarc, surrounded by an outer firmer transparent contractile layer, or ectosarc. It is the ectosarc which is extended to form the collar and flagellum, which we may regard as highly specialised derivatives of pseudopodia. In the endosarc is a conical nucleus, surrounded by numerous granules, and some little blebs of watery fluid, known as vacuoles. Altogether the cell closely resembles some forms of infusoria, and it is of such cells, arranged close together, side by side, that the endoderm is wholly composed.

Before describing the remaining tissues of the sponge, it will be convenient to introduce here a short account of its physiology, so far as the knowledge we have now attained of its structure makes possible.

The flagella of the endodermic cells, which, as we have already noticed, form a continuous lining to the inner wall of the radial tubes, are almost always in motion, bending downwards with a rapid movement in one direction and then returning to their position of rest, and doing this so rapidly that the eye cannot follow them in the active state, so that usually they are quite invisible. Each movement of the flagellum 'flicks' the water, as it were, in one direction, and the rapid successive movements of the almost infinitely numerous flagella drive the water out of the radial tubes into the stomach of the sponge, from which it emerges,

to the ectoderm, though it appears to me that it might more naturally be regarded as endoderm.

as we have already stated, in a powerful stream through the mouth. But as water is driven out of the radial tubes the pressure within them is diminished, and to restore equilibrium,—to supply the place of the water which has been expelled,—fresh water flows in from the interior through the pores at the ends of the tubes, and also, after passing down the inter-canals, through the pores at the sides of the tubes.

The circulation thus established from the pores through the radial tubes into the stomach, and so out through the mouth, is the means through which, as we shall now see, the nourishment and respiration of the sponge are carried on.

The water in which the sponge lives is inhabited by a large number of infusoria and other minute forms of life, and contains besides many small particles derived from decaying organisms; these enter the sponge, borne along with the inflowing currents of water, and are seized upon by the flagellate cells of the endoderm, as they pass through the radial tubes.

The manner in which the flagellated cells extract their food from the water is worth noticing; it is precisely similar to that in which the flagellated monads, which so closely resemble these cells, feed. No sooner does a little particle of food touch the edge of the delicate collar which surrounds the collum, than it adheres to it and is carried down by currents, that circulate up one side of the collar and down the other, to the end of the collum, in which, along with an accompanying drop of water, it becomes at once engulped. If the particle should come directly in contact with the collum itself, it is engulped in the same way. The included drop of water, enclosing its particle of food, travels down the collum into the base of the cell, where it forms a little 'bleb,' which we have already noticed as a 'vacuole.' The food of the vacuole undergoes digestion, and when all the 'goodness' has been got out of it, the indigestible residue is extruded from the cell, through an extemporised aperture, to be forthwith swept away in the torrent

of the circulation, through the stomach, and then out by the mouth. In this way each flagellated cell eats and drinks, living to itself. It also breathes, the water which conveys its food containing dissolved oxygen, which passes into the cell by osmosis. Thus with food for fuel, and oxygen to burn it, the cell is provided with energy, which it expends in maintaining the water circulation, from which it obtains food and oxygen again. Though each cell lives its own life, yet the different cells all work more or less in unison; thus when they have taken enough food to satisfy their wants for the time, they frequently rest together to digest it; more or fewer of them cease to lash the water, the ostia and pores are closed by the contractile sphincters, which also seem to be in sympathy, and the circulation goes on feebly, or, for a time, altogether stops, to begin afresh when digestion is completed, and hunger urges the cells to renewed activity. Though the flagellated cells live each, as has been stated, their own life, yet it is no less true that each lives for the rest of the organism, as indeed must happen in all organised communities. The nutrition received is, under favourable circumstances, more than enough to make good the loss of substance involved in work, and the surplus leads to that increase in size, which is termed growth.

But to increase in size, there is in every individual a limit, which overpassed usually leads to division, and thus soon after the flagellated cell has passed its full size, a constriction makes its appearance transversely round the basal part, and extends inwards till the lower part of the base is completely severed from the rest; in this way the single cell becomes two, one of which retains its original character, while the other resembles an amœba, and making its way into the mesoderm lives a wandering life, possibly like a colourless blood corpuscle, serving as a food carrier to the rest of the organism. This is the origin of the third kind of cells which we mentioned as forming a part of the mesoderm. The splitting or fission of the flagellate cell is not always transverse;

sometimes it is longitudinal, and then produces two similar flagellated cells, instead of a flagellated and an amœbiform cell. It is by longitudinal fission that the endoderm grows in extent, correspondingly with the growth of the surface it covers.

We will now resume our description of the structure of the sponge.

The *Skeleton.*—The soft tissues of the sponge require some kind of support, and this is afforded to them by the hard parts, or skeleton. This consists of needle-shaped, tri-radiate, and quadri-radiate spicules, disposed in a definite manner. The proper wall of the stomach is furnished with three and four-rayed spicules, three of the rays of the quadri-radiate, and all those of the tri-radiate spicules, lying in the substance of the wall, parallel to its surface, while the fourth ray of the quadri-radiate spicules projects with a gentle upward curve into the gastric cavity, carrying the gastral membrane with it.

The radial tubes are furnished with tri-radiate spicules, arranged in successive, concentric, or transverse rows. The form of each spicule is such that two of its rays, those including the largest angle, may be taken to form a pair, the third ray being therefore 'odd;' and they are so arranged that the paired rays lie concentrically, while the odd ray lies longitudinally, in the wall of the tube. The paired rays, which form the basal or proximal row of each radial tube, lie back to back, as it were, with the spicules of the stomach wall, which is thus doubly strengthened.

The outer ends of the radial tubes are furnished, in addition, with colossal fusiform spicules, each often 3 mm. long; these are embedded at one end in the tissue of the tube, and at the other project freely beyond it; about the base of each colossal spicule there is usually a pencil of similar, but much smaller spicules, and a few large grapnel-like spicules are also present. The spicules, large and small, thus projecting from the end of the tube in the form of a brush or pencil, give to the surface of the sponge the

hairy appearance, to which attention has already been directed.

The spicules of the corona, are partly colossal spicules similar to the foregoing, partly tri-radiate and quadri-radiate spicules, with three rays of the latter and two of the former embedded around the mouth, the remaining ray in each case projecting vertically upwards.

This nearly completes our account of the structure of the sponge; that which remains, the nature of the reproductive organs, will form a natural introduction to the account of its life-history.

Certain amœboid cells have already been described as inhabitants of the mesoderm, and the origin, or probable origin, of these cells has also been pointed out. What the subsequent history of them all may be we do not yet surely know, but some of them, at all events, continue for some time wandering through the mesoderm, and instead of contributing food to the rest of the sponge, obtain their nutriment from it, like parasites; thus they grow big, at the same time they become lazy, and at length cease to move about at all; then they assume a spherical form, and remain stationary in a cavity of the mesoderm. If they now retain their simple cell-form, simply increasing in size, they are known as *ova.* Some of them, however, undergo a structural change (at least, so we infer, for this is one of the stages in the history of the sponge which has not yet been directly observed), and as a result of this change, the nucleus of the cell disappears, and the cell itself becomes fibrillated, the fibres all radiating from the centre of the cell to the exterior. It is now called a *sperm-ball.* When it becomes mature, the fibres within are set free; each consists of a little highly-refractile conical head, with a long tail, which vibrating rapidly, propels the *spermatazoon*, as the structure is called, head foremost through the water.

The *spermatazoon* is the male element, the *ovum* the female element of the sponge. Both occur in the mesoderm. It is a

singular thing that the male elements have not yet been discovered in *Sycandra raphanus*, but they have been seen in various other sponges; in some species occurring in the same individuals as contain the ova, in others in different individuals, so that some sponges are hermaphrodite, and others bisexual.

If the ova and spermatazoa be kept separate from each other nothing remarkable will happen, each will lead its own life, and die a natural death. But they do not as a rule remain apart; the spermatazoa when set free on the disruption of the sperm balls, are carried away in the out-flowing water from the radial tubes of one individual, to enter along with the incurrent water the radial tubes of another. Should this latter contain ova, the spermatazoa on approaching an ovum swim towards it like so many tadpoles, and striking it head foremost, with their tails streaming outwards, remain for a while radiately disposed about its circumference. Finally they enter the substance of the ovum, are absorbed and disappear. The ovum is then said to be impregnated. Unfortunately this process, though it has been witnessed in many other sponges, has not been observed in *Sycandra raphanus*. As a consequence of the fusion of the spermatazoa with an ovum, the latter undergoes a remarkable series of changes, which end in producing a fresh sponge like the parent. First of all the nucleus disappears, and after awhile two fresh nuclei appear in its place; a constriction then occurs round the exterior of the ovum, as a shallow furrow, which deepens, extending inwards between the two nuclei till it actually divides the ovum into two parts, each of which has the value of a true cell. The direction in which this division takes place is constantly from the top of the ovum (that side facing the endodermal layer), to the bottom, or as we may briefly formulate it—perpendicular. The cells resulting from the division are flattened below and also against each other, but rounded off towards the top, so that they may be said to diminish in size from the base upwards. They soon undergo the same kind

of change as the parent ovum, the nucleus of each disappears, and is replaced by two fresh nuclei, each is then furrowed by a constriction, and eventually divided into two cells. The plane of division is still perpendicular, but at right angles to the previous one. The four cells thus resulting resemble the parent cells in being broad and flat below, and narrower towards the top; they are likewise flattened against each other, but rounded off along their inner perpendicular edges, so as to leave a small cavity or canal in the axis of the group. This canal is the beginning of what we shall know hereafter as the cleavage cavity. Division again takes place, and still in a perpendicular direction; each of the four cells is divided into two from top to bottom, and thus eight cells arise, which form a ring, surrounding the cleavage cavity, and narrowing from the base upwards. After these three perpendicular divisions, which have given us first two, then four, and finally eight, cells, a fourth one occurs, which is horizontal, and so at right angles to all the preceding ones. As the tops of the cells, previous to this division, were, as stated before, smaller than the bottoms, so it follows that the eight upper cells above the median plane of division are smaller than the eight lower cells beneath it. The embryo consists now of 16 cells in two rows, an upper or apical row, and a lower or basal row, of eight cells each, surrounding the cleavage cavity, which opens by a wide lumen below, and a much narrower aperture above. The embryo exchanges now its plano-convex or cake-like for a cushion-like, or biconvex, form. Two more divisions, also in a horizontal direction, now succeed, severing each ring into two, and thus producing a four ringed form; one ring is apical, one basal, and the two between may be called equatorial. The cells of the equatorial rings are again divided, and this time vertically, in a meridional direction, we might say; in this way each equatorial row comes to contain sixteen cells. The embryo now is a cushion-like sac, the wall being composed of a single layer of similar cells, forty-eight

in number, sixteen in each equatorial ring, and eight in each polar ring. The number of cells is further increased by division, the sac becomes more spherical in form, and the apical end of the cleavage cavity closes up. The next stage in the development is a differentiation of the cells, the eight which surrounded the basal opening of the cleavage cavity, and which are larger than the rest, acquire a dark appearance, owing to the development of a great number of dark granules within them. The remaining cells are muoh clearer, and multiplying in number, are converted into elongated small prism-like cells, radially arranged. The basal end of the cleavage cavity now closes up, and the dark granular cells increase in number. The next stage is either abnormal, inconstant, or in any case subsequently reversed; in it the layer of granular cells becomes flattened, depressed, and then pushed into the cleavage cavity, which is thereby diminished, or even almost obliterated, the granular cells applying themselves to the inner face of the prismatic layer. The form so produced is similar to the gastrula of other animals, but it is not permanent, the granular cells withdrawing themselves, and subsequently resuming their former position.

We may, therefore, return to the larva, where we left it in the normal course of development. The embryo is now more or less egg-shaped; the smaller end consists of the numerous small clear prismatic cells, which are now furnished with flagella, projecting from their outer ends; the larger end consists of the fewer (32) larger, rounded, dark, granular cells, sixteen of which are arranged to form a girdle round the equator, next to the prismatic half. The cleavage cavity still exists as a more or less spherical space in the middle, bounded half by the pigmented ends of the prismatic cells, half by the granular cells. By the movements of its flagella the larva now is liberated from its encapsuled cavity in the mesoderm, passes through the endodermal layer, into the radial tube, and so, borne along by the out-flowing currents of the circu-

lation, out of the sponge into the surrounding water, where it spins about in a lively whirling kind of dance. As it grows, the little 'blastula,' as it may now be called, becomes less ovate and more spherical, and then commences to pass through one of the most important stages of its existence; the flagellated layer begins to lose its spherical contour, becomes flattened, depressed, and is at length drawn quite within the hemisphere of granular cells; it then applies itself to the inner face of this layer, entirely obliterates the cleavage cavity, and thus gives rise to the true *gastrula* form. It will be seen that the embryo is now somewhat bee-hive shaped, its wall is double, consisting of an outer ectodermic layer of granular cells, and an inner endodermic layer of prismatic cells, the cleavage cavity has disappeared, and a new cavity with a widely-open aperture below has arisen by invagination. This aperture is bounded by the row of sixteen granular cells, which previously formed the equatorial girdle of the embryo, they now grow radially inwards towards the centre of the aperture, and thus diminish its area, till it becomes reduced to a comparatively small opening; it is the larval mouth, as the cavity produced by invagination is the larval stomach. So far the larva has led an active, if not an industrious, existence, with the continual promise of better things; it now proceeds to a step, which, in the history of animal development, has generally proved fatal to further progress of importance, and has indeed often led to change in a backward direction. Settling down on some fixed object, such as a bit of stone, or the stem of a seaweed, it exchanges a free for a fixed and stationary existence. The granular cells surrounding the mouth grow inwards towards its centre, and completely obliterate it, at the same time they grow outwards over the surface of attachment in transparent, irregular, jagged, pseudopodia-like processes, which solder the young sponge securely to its seat.

By the absorption of a part of their granules, the granular cells lose, to a great extent, their opacity, so that one can see the layer

of prismatic, or cylindrical cells, through them. They have, evidently, at this stage, lost their flagella. By excretion, or alteration, of the granular cells, a thin layer of jelly-like material is formed between the two layers of the embryo, this is the beginning of the future mesoderm, and in it the spicules as delicate needle-shaped forms first make their appearance. As they grow they soon enter the outer, or ectodermic, layer.

The larva grows in the direction of its axis, and so elongates into a cylindrical or conical body, the distal end flattens, and becomes perforated by a hole which puts the stomach cavity into communication with the surrounding water. This hole is the adult mouth, the endodermal cells retreat from it, leaving the ectodermal layer alone around it, as a clear thin membrane terminating the gastral cavity. Little round spaces open in the side-walls of the sponge and form the pores, the endodermal cells acquire their characteristic collar and re-acquire their flagella. Simultaneously with these changes additional spicules appear. The double-pointed needle-like spicules projecting obliquely upwards and outwards, form a sort of tube, extending from the base to the summit; immediately round the basal edge and the summital edge, they project outwards at right angles, forming a kind of collar. Mingled with the basal spicules are those with toothed ends before alluded to as grapnel-like spicules. Between the needle-like spicules are tri-radiate ones, all similarly arranged, two rays being directed, more or less concentrically, and the third longitudinally and downwards. Quadriradiates also make their appearance, and first round the terminal edge, two of their rays lying in the edge, one being directed longitudinally downwards, the other radiately towards the mouth, and serving as a support for the oral, or terminal, membrane. They are usually 4, 6, or 8 in number at first, and are always symmetrically arranged.

The description of the young sponge is so far complete; it consists of a sac, with a mouth at one end and pores at the sides,

spicules to support it, and with three layers of tissue composing the wall, the ectodermal covering of plate-like cells, the jelly-like mesoderm in the middle and the flagellated endodermal cells within. But, as yet, there is no trace of the radial tubes. Some sponges (*Olynthus*) which have the same developmental history as Sycandra, up to this point, remain persistently in the stage now reached by it; in the young Sycandra, however, budding now begins to take place from the stomach wall, little hollow processes jut out from it, as if pushed out by a finger, these grow outwards, till they acquire exactly the same characters as the sac from which they proceed; the open gastral ends correspond to the mouth of the stomach, and the outer ends of the tubes to the base of the stomach. These are the radial tubes, and at first they are separate from each other, not united; this stage in the history of the sponge remains permanently throughout life in a related species (S. coronata); in our sponge, however, they soon become united by transverse bars of tissue, which cross from one tube to another. The ends of the tubes, however, always remain free as little conical protuberances, but in another sponge (S. capillosa) development proceeds the one step further, and the tubes become joined right up to their extremities. The fact here illustrated, that a stage which is transitory in the history of one animal is persistent in another, is one of the strongest arguments 'for Darwin.'

After so much pure description one may fairly be allowed to indulge in a little speculation; at one time people who thought at all about the matter were accustomed to believe that the young animal was produced from the adult all at once, at a single stroke; it commenced as a minute germ, a more or less exact likeness of the parent in miniature, which had nothing to do except to grow big; such, however, is as we can see, the very opposite of being the case, a vast number of phases of development intervene between the fertilized ovum and the young

sponge. What then is the meaning of these phases, why all this complicated process, instead of the simple impress of the parental image on a young germ? The explanation which has the merit of being at once the simplest and the most rational, is that the various stages in the development of the individual mark the various stages in the history of the species; they present us, in the course of a few days, with a summary very much abridged of the successive steps by which the organism, as it at present exists, was evolved in the course of ages from some simpler form of life. Thus to confine ourselves to the history of the sponge which we have now made our own, we may assume that its earliest ancestor was a simple cell, closely resembling an ordinary amœba, this amœba, after leading a wandering life, feeding and growing big, became stationary, folded its arms, to speak symbolically, withdrew them into itself, and formed a spherical ovum; this either with or without fusing with another individual previously, split into two, as amœbas in such circumstances do at the present day, but the resulting twins, instead of separating from one another, as ordinary young amœbas do, remained in contact, for no obvious reason that one can see unless to keep each other warm; they grew up till the time came for them to split as their parent did, and thus four cells were produced, and so the process continued, all the young cells sticking together on the principle of co-operation. But co-operation by itself will not produce very great results; it frequently, however, leads to something much more important, and that is the specialisation of function and the differentiation of parts; here, in the cluster of young amœbas, such a specialisation took place, some became set apart as food providers and agents in locomotion, their pseudopodia becoming converted into flagella (one wishes one knew how), the others served some other purpose, perhaps of secretion, perhaps as storers of nutriment, and perhaps as reproductive agents. So far the corals, sea-anemonies, and such like creatures (cœlenterata)

appear to have travelled along very much the same road as the sponges, but now they part company, the cœlenterata originated in the growth of the ciliated cells over the cilialess cells, so that the latter formed the digestive lining inside the resulting *gastrula*, as we have agreed to call the sac formed by the invagination of the preceding form or blastula; in the sponges, on the contrary, as we have seen, the ciliated cells withdraw into the cilialess layer, which thus becomes a protecting, instead of a digestive, layer. But now it is worth while recollecting that though this is the normal process with the sponge, yet that the opposite one is frequently passed through as a transitory stage, preliminary to it, and thus we may conjecture that the larva which becomes a sponge now, by invagination of the ciliated layer, is a descendent of a form which used to become a coral by the invagination of the other layer, that is, that a form on the way to become a cœlenterate, took the wrong turn for once, and so ended in a cul-de-sac, and became a sponge. Thus the abnormal kind of invagination in Sycandra may be an instance of what is termed 'reversion to the ancestral type'; on the other hand it may simply indicate the balancing play of forces on the young organism, so that it looks as if it could not make up its mind, and was undecided as to whether to turn the flagellated layer inside and become a sponge, or outside, and become a cœlenterate. Between these alternative possibilities we cannot decide, the day has not yet come when the development of an animal may be represented by a mathematical formula, and that wonderful man, the mathematical physicist, has not yet taken the matter in hand,

To resume our history. The young gastrula, which we believe to have led an independent life, a free swimmer in the sea, whose parent lived and died a gastrula, took another step in development, by becoming sessile, and here again its contrary disposition was displayed, for instead of settling base downwards, as the cœlenterate gastrula did, when it similarly resigned a free existence, it

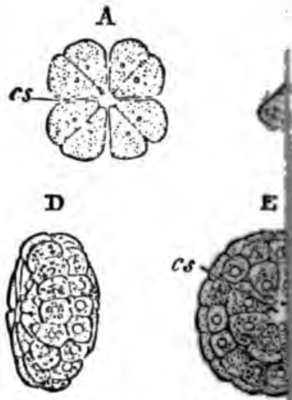


FIG. 1.—Successive stages in t
(Copied fr

A. Stage with eight segments s
B. Side view of stage with ei
C. Side view of stage with si
D. Side view of stage with fo
E. View from above of stage
F. Side view of embryo in the
cells which give rise to t
the lower pole.
cs. Segmentation cavity; ec. g
en. clear cells which f

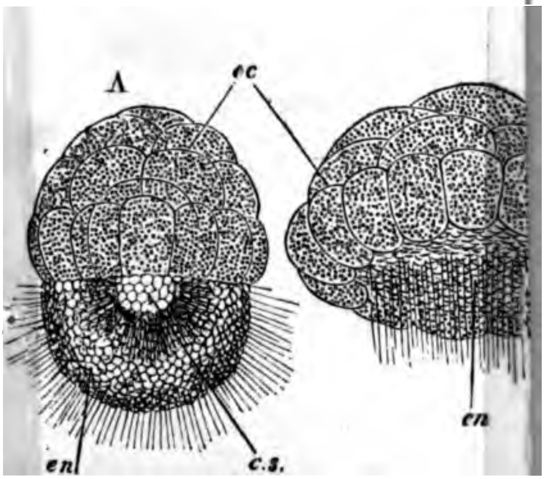


FIG. 3.—Two free stages in the development of Sycan
(Copied from F. E. Schulze).

A. Amplisblastula stage.
B. A later stage, after the ciliated cells have commen
invaginated.
cs. Segmetation cavity; ec. granular cells which form t
en. ciliated cells, which become invaginated
endoderm.

contrary, attached itself by the mouth, which, by subsequent became obliterated. Hence the origin of pores, and the hich we conventionally call the mouth. We have already that some sponges remain their whole life through in the stage now reached, giving rise to other sponges, which no ss beyond it than their parents did; yet in the history of the , there must have been a time when one of these simple progressed a step further and produced the additional com- n of radial-tubes. These are simply so many repetitions of ng Olynthus budded out from its sides, and thus again we -operation, a number of young Olynthi, remaining attached r to form the wall of the Sycandra. But they all perform ie functions; the succeeding and more important step, the ment, by some of the tubes, of one set of functions, and by of another, has not yet taken place; some day, perhaps it he future is infinite with possibility, and Sycandra may even destined to a brilliant and successful career.

On some Cases of Prolification in "*CYCLAMEN PERSICUM*,"

By ADOLPH LEIPNER, F.Z.A.

HAVING, during the last two years, met with several cases of Prolification, or of formation of adventitious buds in Cyclamens, the author thought it right to draw the attention of the members of the society to this interesting phenomenon. The two cases illustrated here explain themselves: in one specimen (*plate* IV. *fig.* 2) the *flower*-stalk, instead of normally terminating in one solitary flower, has produced a small leaf immediately below the calyx of that flower, and another leaf, with a small axillary flower-bud, about one half-inch below;—in the other case (*plate* IV. *fig.* 1) the *leaf*-stalk has produced, at a distance of about two inches from its origin, another plant with one leaf and three flowers. In a third case, which the author exhibited, the leaf-stalk branched, and formed four fully developed leaves, with one diminutive flower-bud in the axil of each leaf. Prolification occurs, therefore, in these plants, both upon the inflorescence and upon the leaves.

The two plants of cyclamen, which produced these abnormal growths, had been obtained from Messrs. Garaway; and on examining their stock, a short time ago, several more instances of it were discovered. It would be interesting to observe whether this prolification has a hereditary tendency;—as yet the author has not been able to get seed from proliferous flowers, but is desirous to do so, in order to experiment with it.

It would appear that the first of these three cases, thus briefly described, may be similar to the two referred to by Dr. Masters in his "Vegetable Teratology," p. 104.

Fig I

Fig II

The Ethnology of the Paropamisus or Hindoo Koosh.

BY JOHN BEDDOE, M.D., F.R.S.

THIS subject was treated under the following heads :—The geography of the countries, their history as regards ethnology, and the various races inhabiting them. As to the geographical characteristics of this region, it was highland as compared with most of the surrounding countries, consisting mainly of ranges of hills enclosing narrow valleys and small elevated plains, and radiating from two principal ranges, the Hindoo Koosh, running nearly east and west, and the Suliman mountains, nearly north and south. The former is not really a prolongation westward of the Himalayah, which does not cross the Indus, and is represented, if at all, by the Safed Koh (White Mount) range, south of the Kabul river: this range terminates to the west in knots of mountains, among which lies the Shutargardan Pass, of which we have heard so much of late. As we proceed southwards and westwards the elevation of the country decreases, and we find considerable diversity of climate. The north-western portion is of a more open character, the central and eastern parts are well wooded and watered, while in the west, pasture is the chief feature and wood is scarce. The streams flowing southwards never reach the sea, but converge towards the small lake of Seistan, from which there is no outlet.

The various tribes which inhabit this region present great varieties of character; the Ghilzais (the second in population and importance of the Afghan clans), and Kaffirs being the most warlike and indomitable, while others, though nominally under the sway of a sovereign, are very much in the position of the Scottish clans in olden times. Most of these are regarded as branches of the great Aryan race, and this opinion obtains support from the references in the Zendavesta to the regions beyond the river Oxus, whence the Aryans issued. Alexander the Great during his conquests found Aryans only, it would seem, in these regions, but Grecian historians considered the more Eastern of them to be Indians rather than Persians, and doubtless they judged by their language and physical aspect. The fact, of small statuettes of classical form having been found in some of these parts, indicates the people to have been advanced to some extent in civilization under the Græco-Bactrian kingdom. Dr. Leitner, of Lahore, has made some interesting discoveries of this nature. The inhabitants of Afghanistan are, ethnologically, classed under two great divisions, viz., Iranians, or Aryans, and Turanians, each of which is again sub-divided into numerous tribes. The former comprise the Kaffirs, Jats, Hindkis, Badakshis, Sarts, Tajiks, Biluchis, and the Afghans, or Patans; while the latter include the Uzbeks, Kizilbashis, Huzarehs, and Eimauks. The physiognomy presents different types; we have some of a Jewish cast, others showing more or less of a Tartar cross, while the Persian type, as shown in the Persepolitan sculptures, is exemplified in the Tajiks, who are scattered over the west and north-west. The Kaffirs are said to be distinguished by light hair and eyes. The Huzarehs, who speak the Persian language, and profess the same religion with the Persians, are allied to the Mongols in blood, and their physical characteristics, such as short stature, narrow oblique eyes and broad cheek-bones, still attest their descent, which is supposed to be from the armies of Jenghiz Khan. As to the origin of the Afghans proper, some few, among whom is Dr. Bellew, lean to

the opinion that they are of Jewish descent, and base their theory on several peculiarities, which seem at first sight to favour their views, such as the form of features, especially the nose; the practice of certain customs once thought peculiar to the Jews, *e.g.*, the ceremony of the scapegoat, punishment by stoning, &c. Saul, the son of Kish, is regarded by the Afghans themselves as their ancestor, though much weight cannot attach to this tradition, which is probably of comparatively modern date, and borrowed from the Arabs. Mountstuart Elphinstone, on the other hand, basing his opinion chiefly on the language, regards them as of Perso-Aryan origin, and his authority carries the greatest weight; in fact all, or nearly all, ethnologists subscribe to this view. It is curious that the Povindahs, the most mercantile clans among the Afghans, seem to be among those who approach most distinctly to the Jewish type of features, while in the portraits of Duranis, Ghilzais, Momunds, and other military and pastoral tribes, there does not appear to be anything Semitic.

Catalogue of the Lepidoptera of the Bristol District.

PART 3.

BY ALFRED E. HUDD, M.E.S.

NOCTUÆ.

THYATIRA DERASA. L. Generally distributed throughout the district, but not common.

„ BATIS. L. Generally distributed and sometimes common.

CYMATOPHORA DUPLARIS. L. GLOS. Almondsbury, Rudgewood, Cook's Folly Wood, Wotton-under-Edge, Woodchester.

SOMERSET Bedmiminster. R.F. Leigh Woods, Portishead, Weston-super-Mare. Not very common.

„ DILUTA. W.V. GLOS. Clifton, Wotton-under-Edge.

SOMERSET. Leigh Woods, Portishead, Weston-super-Mare. Not uncommon.

CYMATOPHORA OR. W.V. GLOS. "Bristol and Cotswolds."—"*Stainton's Manual,*" *I., p. 175.*
SOMERSET. Portishead Woods. J.M.D. "Common at sugar."

„ [OCULARIS. L. Not recorded from my district, but reported from the neighbourhood of Taunton, Somerset, by Mr. F. Stansell, in 1874.—See *Entomologist* VIII., p. 159.]

„ FLAVICORNIS. L. GLOS. Clifton.
SOMERSET. Leigh. Scarce in Birch-woods.

„ RIDENS. F. GLOS. Clifton and Durdham Downs.
SOMERSET. Brislington, by Mr. Sircom; Brockley and Leigh Woods. Scarce.

BRYOPHILA GLANDIFERA, W.V. Generally distributed and often common on old walls..

„ PERLA. W.V. Common everywhere.

ACRONYCTA TRIDENS. W.V. GLOS. "Bristol:" *Stainton's Manual.* Redland. P.H.V.
SOMERSET. Wells and Weston-super-Mare. Scarce.

„ PSI. L. Common everywhere.

„ LEPORINA. L. GLOS. Stapleton. G.H. Wotton-under-Edge.
Somerset. Bath, Bedminster, Leigh Woods, Wells. Not common.

„ ACERIS L. SOMERSET. Recorded only by Mr. Crotch. "Near Weston-super-Mare."

„ MEGACEPHALA. W.V. Generally distributed, the larvæ being sometimes common.

„ ALNI. L. GLOS. A specimen was bred in May, (1855 ?) from a larva found the previous autumn on hawthorn, at Almondsbury, by Mr. Allen Hill. A larva taken by Mr. Harding at Stoke

Gifford, on apple, produced an imago the following spring. A fine male was bred by the Rev. Jos. Greene, on April 29th, 1878, from a larva found the previous year in the Gully, on hazel. Mr. Greene also found, some time previously, a dead larva at the foot of an elm tree at Stapleton. An imago found at rest on a stone-wall at Woodchester, in July, 1879, is recorded by the Rev. H. S. Gates, O.P.; also a larva in the same locality in 1880.

SOMERSET. Reported only from Leigh Woods and Portishead. This species seems to be widely distributed throughout the country, but is everywhere scarce, probably in consequence of the larvæ being so susceptible to attack from *hymenopterous* and *dipterous* parasites. The moth is very rare on the Continent, and is therefore not in every British collection.

ACRONYCTA LIGUSTRI. W.V. Generally distributed throughout the district, but scarce.

„ RUMICIS. Generally distributed and common

LEUCANIA CONIGERA. W.V. Generally distributed and not scarce.

„ LITHARGYRIA. E. GLOS. Durdham Down, Stapleton, Wotton-under-Edge, Woodchester.

SOMERSET. Brislington, Wells, Weston, &c.

„ LITTORALIS. C. GLOS. One specimen at sugar at Stapleton, by Mr. Harding.

SOMERSET. Weston-super-Mare. G.R.C.

„ COMMA. L. Generally distributed and common.

„ STRAMINEA. T. SOMERSET. Dr. Livett reports this species from marshes near Wells, and it is also marked on Mr. Crotch's list from Weston-super-Mare.

LENCINEA IMPURA. H. Generally distributed.

„ PALLENS. L. Generally distributed.

NONAGRIA DESPECTA. T. GLOS. One specimen only, taken by Mr. W. H. Grigg, on a gas-lamp near Cotham.

„ FULVA. H. Glos. Baptist's Mills and Clifton. SOMERSET. Leigh Down, Weston-super-Mare, etc. Scarce.

„ GEMINIPUNCTA. H. SOMERSET. Taken rather freely in the larval state, by the late Mr. Crotch, near Weston-super-Mare.

„ TYPHÆ. E. GLOS. Wotton-under-Edge. V.R.P. SOMERSET. Brislington and Weston-super-Mare. Scarce.

„ LUTOSA. H. GLOS. Almondsbury, Baptist's Mills, Cotham, Stapleton, Wotton-under-Edge. SOMERSET. Leigh, Weston-super-Mare.

GORTYNA FLAVAGO W.V. Generally distributed throughout the district; the larvæ sometimes abundant in thistle stems.

HYDRÆCIA NICTITANS. L. GLOS. Ashley Hill, Almondsbury, Stapleton, Wotton-under-Edge. SOMERSET. Bath, Keynsham, Weston-super-Mare. Not common.

„ MICACEA. E. Generally distributed.

AXYLIA PUTRIS. L. Generally distributed, but not often common.

XYLOPHASIA RUREA. F. Throughout the district, sometimes abundant. The variety *Combusta* sometimes comes to sugar at Almondsbury, Stapleton, &c., but is scarce.

„ LITHOXYLEA. W.V. Generally distributed, but not very common.

„ SUBLUSTRIS. E. GLOS. Stapleton, "*Bristol*," Woodchester, SOMERSET. Brislington. Scarce.

XYLOPHASIA POLYODON. L. Common everywhere.

„ HEPATICA. C. GLOS. Durdham Down, Horfield, Stapleton; "Larvæ and pupæ common under moss at Woodchester."—Rev. H. S. Gates.

SOMERSET. Bath, Portishead, Wells, Weston-super-Mare. Sometimes common at Sugar.

„ SCOLOPACINA. E. SOMERSET. One specimen taken 1875, at Wells, by Dr. Livett. Weston-super-Mare. G.R.C.

DIPTERYGIA PINASTRI. L. GLOS. Mr. Perkins writes: "Common at sugar on elms, at Wotton-under-Edge."

SOMERSET. Weston-super-Mare.

[XYLOMIGES CONSPICILLARIS. L. Not recorded from my district, but specimens have been found in both counties: near Gloucester, by Mr. Merrin (*E. An.*, 1869), and Taunton, by the late Mr. Crotch.]

NEURIA SAPONARIAE. B. GLOS. Stapleton, Westbury, Woodchester.

SOMERSET. Bath, Brislington. Scarce.

HELIOSPHOBUS POPULARIS. F. Generally distributed, but not common.

„ HISPIDA H. GLOS. One specimen flying over grass at Clifton, in September, 1866, recorded in "*The Entomologist's Annual*" for 1867, on my authority.

CHARÆAS GRAMINIS. L. GLOS. "Bristol," Almondsbury.

SOMERSET. Bath, Brockley, Leigh Down, Weston-super-Mare. Not common.

CERIGO CYTHEREA. F. GLOS. Durdham Down, Woodchester.

SOMERSET. Leigh Down. Not common.

LUPERINA TESTACEA. W.V. Generally common.

UPERINA CESPITIS. W.V. GLOS. One specimen taken at Redland by Mr. P. H. Vaughan. [Cotswolds].
SOMERSET. One specimen on Leigh Down, Oct. 1879. W.H.G.

AMESTRA ABJECTA H. SOMERSET. This species is marked on Mr. Crotch's list from Weston-super-Mare, which is the only record I have of its occurrence in the district.

„ ANCEPS. H. GLOS. "Bristol," Stapleton, Woodchester, Cotswolds.
SOMERSET. Bath, Brislington, Leigh, &c. Not common.

„ ALBICOLON. H. SOMERSET. Weston-super-Mare. By Mr. Crotch only.

„ FURVA. W.V. GLOS. Durdham Down, Redland.
SOMERSET. Weston-super-Mare. Scarce, at flowers of guelder-rose, &c.

„ BRASSICÆ. L. Abundant everywhere.

„ PERSICARIÆ. L. SOMERSET. Near Bath and Weston-super-Mare. Not common. No records in my district from Gloucestershire.

PAMEA BASILINEA. W.V. Generally distributed, and sometimes common at sugar.

„ GEMINA. H. Generally distributed, but not common.

„ UNANIMIS. T. GLOS. Stapleton, Baptist's Mills, Woodchester.
SOMERSET. Bath, Brislington, Weston. Sometimes common at sugar.

„ FIBROSA. H. GLOS. Wotton-under-Edge. A few specimens only, taken by Mr. Perkins in his garden.

„ OCULEA. F. Abundant everywhere, and greatly varies in colour.

MIANA STRIGILIS. L. Generally distributed and abundant.

MIANA FASCIUNCULA. H. Generally distributed.

" LITEROSA. H. GLOS. Clifton Down, Wotton-under-Edge.
SOMERSET. Leigh Woods, Weston-super-Mare.

" FURUNCULA. W.V. GLOS. "Bristol and Cotswolds," Wotton-under-Edge.
SOMERSET. Bath, Brislington, Leigh, Weston-super-Mare. Not common.

" ARCUOSA. H. GLOS. Almondsbury, Durdham Down, Stapleton, Woodchester.
SOMERSET. Brislington, Bath, Keynsham, Wells, Weston. Not common.

GRAMMESIA TRILINEA. W.V. Generally distributed, and common.

CARADRINA MORPHEUS. H. GLOS. Stapleton, Wotton-under-Edge.
SOMERSET. Bath, Brislington, Weston. Scarce.

" ALSINES. B. GLOS. Stapleton, Woodchester, Wotton-under-Edge.
SOMERSET. Bath, Brislington, Weston, &c.

" BLANDA. W.V. GLOS. Almondsbury, Stapleton, Woodchester, Wotton-under-Edge.
SOMERSET. Bath, Brislington, Leigh, Weston.

" CUBICULARIS. W.V. Common everywhere.

RUSINA TENEBROSA. H. GLOS. Durdham Down, Stapleton, Woodchester, Wotton-under-Edge.
SOMERSET. Bath, Leigh, Weston. Scarce.

AGROTIS VALLIGERA. W.V. GLOS. Wotton under-Edge.
SOMERSET. Weston-super-Mare. Scarce.

" PUTA. H. GLOS. Durdham Down, Stapleton, Frome Glen, &c.
SOMERSET. Bath, Brislington, Wells, Weston. Sometimes abundant at sugar.

AGROTIS SUFFUSA. W.V. Common everywhere.

„ SAUCIA. H. Generally distributed, and common.

„ SEGETUM. W.V. Abundant everywhere.

„ EXCLAMATIONIS. L. Abundant everywhere.

„ CORTICEA. W.V. GLOS. Durdham Down, Redland, Stapleton.
SOMERSET. Bath, Brislington, Clevedon, Glastonbury, Weston-super-Mare.

„ CINEREA. W.V. GLOS. Two specimens only, taken by Mr. George Harding on Durdham Down. Woodchester, by Rev. H. S. Gates.

„ RIPAE. H. SOMERSET. Taken by Mr. Crotch, near Weston-super-Mare.

„ NIGRICANS. L. GLOS. Taken on leek-flowers, at Stapleton, by Mr. George Harding.
SOMERSET. Bath, Brislington, Weston, &c.

„ TRITICI. L. GLOS. Stapleton.
SOMERSET. Bath, Brislington, Weston, &c.

„ AQUILINA. W.V. GLOS. Scarce at Stapleton; by Mr. George Harding.
SOMERSET. Weston-super-Mare.

„ [OBELISCA. W.V. Taken on the Cotswolds by the Rev. E. H. Todd.]—*See E. M. M., 1867, p. 210.*

„ PORPHYREA. W.V. Not scarce on heaths, Durdham Down, Redland, Leigh, &c.

„ RAVIDA. W.V. GLOS. One specimen taken by Mr. Harding at Stapleton. [Cotswolds, by Mr. Todd.]

„ [PYRPOHILA. W.V. Cotswolds, by Mr. Todd.]

„ LUCERNEA. L. GLOS. One specimen taken on Durdham Down by Mr. Vaughan.

TRIPHÆNA JANTHINA. W.V. Generally distributed, and not uncommon.

TRIPHÆNA FIMBRIA. L. GLOS. Stapleton, Woodchester, Wotton-under-Edge.
SOMERSET. Brislington, Wells, Weston. Not very common.

„ INTERJECTA. H. GLOS. Almondsbury, Stapleton, SOMERSET. Bath, Bedminster, Portishead, Weston-super-Mare. Not Common.

„ ORBONA. H. Abundant everywhere.

„ PRONUBA. L. Abundant everywhere.

NOCTUA GLAREOSA. E. GLOS. Not recorded.
SOMERSET. Leigh Woods and Apperton.

„ AUGUR. F. GLOS. Horfield, Patchway, Stapleton, Wotton-under-Edge.
SOMERSET Leigh Woods. Not common.

„ PLECTA. L. Common everywhere.

„ C-NIGRUM. L. Generally common.

„ TRIANGULUM. H. GLOS. "Bristol," Stapleton, Wotton-under-Edge.
SOMERSET. Bath, Brislington, Leigh, Portishead, Weston-super-Mare. Not common.

„ [RHOMBOIDEA. E. GLOS.? Recorded in "*Stainton's Manual*," from Bristol. I know of no captures in the district.]

„ BRUNNEA. W.V. GLOS. "Bristol," Stapleton, Wotton-under-Edge, Woodchester.
SOMERSET. Bath, Portishead, Weston-super-Mare. At sugar, not common.

„ FESTIVA. W.V. Generally common.

„ [DAHLII. H. "Bristol"—"*Stainton's Manual*" only: locality unknown to me.]

„ RUBI. V. Generally distributed, and abundant at sugar.

„ UMBROSA. H. Generally distributed, but not common.

„ BAJA. W.V. Generally distributed, but not common.

NOCTUA NEGLECTA. H. SOMERSET. Recorded from near Weston-super-Mare by Mr. Crotch only.

„ XANTHOGRAPHA. W.V. Abundant everywhere.

TRACHEA PINIPERDA. P. GLOS. Wotton-under-Edge.
SOMERSET. Brockley, Leigh, Portishead, Weston-super-Mare, &c. Larvæ sometimes common in pine-woods.

TÆNIOCAMPA GOTHICA. L. Common everywhere.

„ LEUCOGRAPHA. W.V. SOMERSET. Recorded from Weston-super-Mare by Mr. Crotch.

„ RUBRICOSA. W.V. Generally distributed, and sometimes rather common at sallow-bloom.

„ INSTABILIS. W.V. Common everywhere.

„ OPIMA. H. GLOS. "Bristol," Almondsbury.
SOMERSET. Leigh Woods. Scarce.

„ POPULETI. F. GLOS. "Bristol," Frome Glen, Almondsbury.
SOMERSET. Weston-super-Mare. Scarce.

„ STABILIS. W.V. Abundant everywhere.

„ GRACILIS. W.V. Generally distributed.

„ MINIOSA. W.V. GLOS. One by Mr. Grigg at Stapleton.
SOMERSET. Leigh, Weston-super-Mare. Scarce.

„ MUNDA. W.V. GLOS. Stapleton, Wotton.
SOMERSET. Bath, Leigh, Weston-super-Mare. Sometimes abundant at sallows.

„ CRUDA. W.V. Common everywhere.

ORTHOSIA SUSPECTA. H. GLOS. A few at Downend, by Messrs. Hill & Mayes; Woodchester. H.S.G.

„ UPSILON. W.V. GLOS. "Bristol," Cotham, Stapleton. Abundant at Wotton-under-Edge.
SOMERSET. Brislington.

ORTHOSIA LOTA. L. Generally distributed; larvæ sometimes abundant on willows.

„ MACILENTA. H. Generally distributed, and sometimes abundant at ivy-bloom.

ANCHOCELIS RUFINA. L. GLOS. Almondsbury, Durdham Down. SOMERSET. Leigh, Weston-super-Mare. Scarce.

„ PISTACINA. W.V. Abundant everywhere, and extremely variable.

„ LUNOSA. H. Generally distributed, and common.

„ LITURA. L. Generally distributed, and common.

CERASTIS VACCINII. L. Abundant everywhere.

„ SPADICEA. G. Abundant everywhere.

„ ERYTHROCEPHALA. W.V. GLOS. No record. SOMERSET. Very rare. One specimen taken at sugar at Wells, by Dr. Livett, Oct. 4th, 1874, and one or two near Weston, by Mr. Crotch.—*See* "*Intelligencer,*" *Vol.* III. *p.* 53.

SCOPELOSOMA SATELLITIA. L. Common everywhere.

DASYCAMPA RUBIGINEA. W.V. GLOS. Almondsbury, Clifton, Henbury, Stapleton. SOMERSET. Brislington, Leigh, Wells, Weston-super-Mare. Scarce.

HOPORINA CROCEAGO. W.V. GLOS. No record. SOMERSET. One specimen beaten from ivy-bloom at Leigh, in November, 1866, by Mr. Hutchins; Weston-super-Mare, by Mr. Crotch.

XANTHIA CITRAGO. L. Generally distributed, the larvæ being sometimes common.

„ CERAGO. W.V. Generally distributed, but not common.

„ SILAGO. H. Throughout the district, the larvæ sometimes common in sallow-catkins.

„ AURAGO. W.V. GLOS. Clifton and Durdham Downs.

SOMERSET. Bath, Brislington, Leigh Woods, Portishead. Not common.

XANTHIA FERRUGINEA. W.V. Common everywhere.

CIRRHŒDIA XERAMPELINA. H. GLOS. The Rev. Jos. Greene writes: "Pupæ abundant some years at roots of ash on Durdham Downs. From one of these I bred the variety commonly supposed to exist only in the Isle of Man." A few specimens of the imago have also been found at Almondsbury, Ashley Hill, Bristol, Stapleton, and near Gloucester.

SOMERSET. Brislington, Leigh, &c.

TETHEA SUBTUSA W.V. GLOS. "Bristol," Stapleton, Wotton-under-Edge. [Gloucester.]

SOMERSET. Weston-super-Mare. Scarce.

„ RETUSA. L. GLOS. Almondsbury, Wotton-under-Edge.

SOMERSET. Brislington. P.H.V. Scarce.

EUPERIA FULVAGO. W.V. GLOS. One specimen taken at Redland by Mr. Vaughan; one at Fishponds, in 1875, by Mr. Preston.

SOMERSET. Keynsham. Scarce. R.F.

COSMIA TRAPEZINA. L. Abundant everywhere.

„ PYRALINA. W.V. GLOS. Montpelier, by Mr. Vaughan, [Dean Forest]. Scarce.

„ DIFFINIS. L. GLOS. Almondsbury, Clifton, Durdham Down, Wotton-under-Edge.

SOMERSET. Bath, Brislington, Wells, Weston-super-Mare. Not common.

„ AFFINIS. L. GLOS. "Common in many places round Bristol." P.H.V. Woodchester, Wotton, &c.

SOMERSET. Bath, Brislington, Wells, Weston.

EREMOBIA OCHROLEUCA. W.V. GLOS. "Bristol," Horfield.

SOMERSET. Brislington, Weston-super-Mare.

DIANTHÆCIA CARPOPHAGA. B. Common, & generally distributed.

„ CAPSOPHILA. D. SOMERSET. One specimen reported from Wells by Dr. Livett: named for him by the late Edward Newman.

„ CAPSINCOLA. W.V. GLOS. "Bristol," Stapleton, Wotton-under-Edge.
SOMERSET. Brislington, Leigh, Weston-super-Mare. Larvae sometimes abundant.

„ CUCUBALI. W.V. GLOS. "Bristol," Redland. P H.V.
SOMERSET. Weston-super-Mare. Scarce.

„ CONSPERSA. W.V. GLOS. Woodchester, 1879, by Rev. H. S. Gates.
SOMERSET. Leigh Woods, by the Rev. Jos. Greene; scarce.

HECATERA DYSODEA. W.V. SOMERSET. Weston-super-Mare.

„ SERENA. W.V. GLOS. Fishponds, Stapleton, Wotton-under-Edge.
SOMERSET. Bath, Brislington, Weston.

POLIA FLAVICINCTA. W.V. Common, and generally distributed.

DASYPOLIA TEMPLI. T. GLOS. Almondsbury, Clifton, Redland.
SOMERSET. Weston-super-Mare, and near Taunton. Scarce at light.

EPUNDA LUTULENTA. W.V. SOMERSET. Weston-super-Mare, by Mr. Crotch.

„ NIGRA. H. GLOS. Clifton, Durdham Down, Stoke Bishop.
SOMERSET. Bath, Leigh, Nailsea, Weston-super-Mare. Not common.

„ VIMINALIS. F. GLOS. "Bristol." [Cotswolds].
SOMERSET. Bath, Brislington, Leigh. Scarce.

„ LICHENEA. H. GLOS. Clifton and Durdham Downs, Westbury, Wotton-under-Edge.
SOMERSET. Wells. Scarce.

MISELIA BIMACULOSA. L. GLOS. "Once near Bristol in 1815," *Stainton's Manual, Vol.* I., *p.* 268. The late J. F. Stephens, in his "*Illustrations Haustellata,*" *Vol.* III., *p.* 24, states; "The only indigeneous example (of *M. bimaculosa*) I have seen, is contained in the collection at the British Museum, to which it was presented by Dr. Leach; it was captured near Bristol, I believe in 1815." This specimen is still in the British Museum collection, with Dr. Leach's ticket attached.

„ OXYACANTHAE. L. Common everywhere.

AGRIOPIS APRILINA. Generally distributed, but not very common.

PHLOGOPHORA METICULOSA. L. Abundant everywhere.

EUPLEXIA LUCIPARA, L. GLOS. "Bristol," Stapleton, Wotton-under-Edge.

SOMERSET. Leigh, Wells, Weston-super-Mare,

APLECTA HERBIDA. W.V. GLOS. Durdham Down [Cotswolds].

SOMERSET. Brockley, Weston-super-Mare.

„ NEBULOSA. H. GLOS. Redland, Stapleton.

SOMERSET. Bath, Leigh, Weston-super-Mare.

„ ADVENA. W.V. Generally distributed, but not common.

HADENA ADUSTA. E. GLOS. Bristol, Stapleton, Woodchester.

SOMERSET. Leigh, Portishead. Scarce.

„ PROTEA. W.V. Common, and generally distributed.

„ DENTINA. W.V. GLOS. Clifton, Stoke, Stapleton.

SOMERSET. Leigh Woods, Weston-super-Mare.

„ CHENOPODII. W.V. GLOS. Stapleton, Wotton-under-Edge.

SOMERSET. Weston-super-Mare. Scarce.

„ SUASA. W.V. GLOS. "Bristol."

SOMERSET. Leigh, Portishead, Weston. At sugar, &c. Not common.

HADENA OLERACEA. L. Abundant everywhere.

„ PISI. L. GLOS. Stapleton, Wotton, Woodchester. SOMERSET. Weston-super-Mare.

„ THALASSINA. B. GLOS. Bristol, Stapleton, Woodchester. SOMERSET. Bath, Leigh, Portishead, Weston-super-Mare. Sometimes common at sugar.

„ CONTIGUA. W.V. GLOS. Recorded only from Durdham Down, by Mr. Vaughan.

„ GENISTAE. B. GLOS. Durdham Down, Hortham Wood, Stapleton.
SOMERSET. Brislington, Leigh, Portishead. Not common.

XYLOCAMPA LITHORIZA. B. Generally distributed.

CALOCAMPA VETUSTA. H. GLOS. Almondsbury, Stoke Druid, Horfield.
SOMERSET. Weston-super-Mare. Scarce.

„ EXOLETA. L. Generally distributed, but scarce.

XYLINA RHIZOLITHA. W.V. Generally distributed.

„ SEMIBRUNNEA. H. Generally distributed, but not common.

„ PETRIFICATA. W.V. GLOS. Durdham Down, Westbury, &c.
SOMERSET. Bath, Brislington, Leigh, Wells, Weston-super-Mare. Not common.

CUCULLIA VERBASCI. L. Common, and generally distributed.

„ SCROPHULARIAE. W.V. GLOS. Mr. Perkins writes: "I found several larvae of this moth in June, 1868, feeding on *Scrophularia nodosa*, along the banks of my pond at Wotton-under-Edge, and though I have constantly searched for them, have not seen another since." Mr. Hill met with some larvae in his garden at Almondsbury.

„ LYCHNITIS. R. GLOS. I have lately, through the kindness

of the Rev. H. Gates, been shown a specimen of this local species, captured by him near Woodchester, in August, 1879.

CULCULLIA CHAMOMILLAE. W.V. GLOS. Reported from Westbury, by Mr. P. H. Vaughan.

„ UMBRATICA. L. Generally distributed, but not common.

HELIOTHIS MARGINATA. F. GLOS. No records.
SOMERSET. Brislington, Weston-super-Mare. Not common.

„ PELTIGERA. GLOS. At Clifton, by Mr. Mayes.

„ ARMIGERA. H. GLOS. Clifton, Stapleton (?), Fishponds; Wotton-under-Edge, Aug. 29th, 1878.
SOMERSET. Brislington, Weston, Nr. Taunton, &c.

„ [DIPSACEA. L. GLOS. No records from my district, but taken by the Rev. E. H. Todd, on Cotswolds.]

„ SCUTOSA. W.V. SOMERSET. A fine specimen taken on the coast, near Weston-super-Mare, by Mr. Jones, of Redland, in August, 1876, is now in the rich collection of Mr. W. H. Grigg.

HELIODES ARBUTI. F. Generally distributed, and sometimes common.

ACONTIA LUCTUOSA. W.V. GLOS. Wotton-under-Edge "three specimens in July, 1870." V.R.P.; also near Tetbury Road, Oakley Woods, and on the Cotswolds.
SOMERSET. Weston-super-Mare.

ERASTRIA FUSCULA. W.V. GLOS. "Bristol" (?), Wotton-under-Edge, among coarse herbage in woods. V.R.P.
SOMERSET. Weston-super-Mare. Scarce.
Directions for finding the larvae of this species, on grass *(Molinia cærulea)*, will be found in "*The Entomologist*," VII., *p.* 185.

HYDRELIA UNCA. W.V. SOMERSET. Weston, by Mr. Crotch.

MICRA PARVA. H. SOMERSET. A specimen was captured on Brean Down some years ago, by the late Mr. Crotch.

BREPHOS PARTHENIAS. L. GLOS. No records.
SOMERSET. Birch Woods, at Leigh, and near Wells. Not common.

ABROSTOLA URTICAE. H. Generally distributed, but not common.

" TRIPLASIA. L. Generally distributed.

PLUSIA ORICHALCEA. F. GLOS. A few specimens only, near Dursley, Woodchester, and Wotton-under-Edge, by Messrs. Phillips, Gates, and Perkins.—*See The Entomologist Vol.* XII., *pp.* 221-227. Mr. Perkins writes: "Nine specimens were found in 1868, but not one would come to sugar."

" CHRYSITIS. L. Generally distributed.

" FESTUCÆ. L. SOMERSET. One specimen taken at Brislington, by Mr. Grigg. Weston-super-Mare, by Mr. Crotch.

" IOTA. L. GLOS. Almondsbury, Horfield, Redland, Westbury, Woodchester, Wotton-under-Edge.
SOMERSET. Bath, Brislington, Wells, Weston-super-Mare. Not generally common.

" V-AUREM. G. Generally distributed, & sometimes abundant.

" GAMMA. Abundant everywhere.

GONOPTERA LIBATRIX. L. Generally distributed.

AMPHIPYRA PYRAMIDEA. L. Common, and generally distributed.

" TRAGOPOGONIS. L. " " "

MANIA TYPICA. L. " " "

" MAURA. L. " " "

TOXOCAMPA PASTINUM. T. GLOS. No records.
SOMERSET. Weston-super-Mare. Not common.

[STILBIA ANOMALA. L. Not recorded from the Bristol District, but is not uncommon in North Devon.]

CATOCALA FRAXINA L. SOMERSET. A specimen of this very rare and beautiful moth, in rather worn condition, was taken at sugar in Leigh Woods, on Sept. 1st, 1880, by Mr. G. C. Griffiths, and was exhibited by him at the October meeting of the Entomological Section of our Society.—*See "The Entomologist," p.* 241.

" NUPTA. L. Generally distributed, and sometimes common at sugar.

" PROMISSA. W.V. GLOS. Used to be found round oak-trees in Over Park, Compton Greenfield. P.H.V.

" SPONSA. L. GLOS. Over Park P.H.V.

EUCLIDIA MI. L. Generally distributed, but local.

" GLYPHICA. L. Generally distributed, but not common.

PHYTOMETRA AENEA. W.V. GLOS. Durdham Down, Woodchester, Wotton-under-Edge. SOMERSET. Leigh, Clevedon, Weston-super-Mare. Common on heaths and downs.

The Fungi of the Bristol District.

PART 3.

BY CEDRIC BUCKNALL, Mus. Bac.

	AMANITA.		
502.	Agaricus strangulatus, *Fr.*	Leigh Wood,	Sept. 1879.
	TRICHOLOMA.		
503.	Agaricus murinaceus, *Bull.*	Stapleton Park,	Oct. „
504.	„ saponaceus, *Fr.*	Leigh Wood,	„ „
	CLITOCYBE.		
505.	Agaricus cerussatus, *Fr.*	Coombe Dingle	„ 1878.
506.	„ metachrous, *Fr.*?	Glen Froome,	Nov. 1879.
	PLEUROTUS.		
507.	Agaricus tremulus, *Schaeff.*	Leigh Wood,	Oct. „
	COLLYBIA.		
508.	Agaricus confluens, *Pers.*	Tyntesfield,	July, „
509.	„ cirrhatus, *Schum.*	Leigh Down,	Oct. „
510.	„ xanthopus, *Fr.*	Brintry,	May „
	MYCENA.		
511.	Agaricus vulgaris, *Pers.*	Leigh Down,	Oct. „
512.	„ roridus, *Fr.*	Clifton,	May „

This species grew on dead bramble which had been kept in the water during the winter.

513. Agaricus sacchariferus, *B.&Br.?* Leigh Down, Oct. „

On dead furse, bracken, &c.—This is smaller and more delicate, and has fewer gills than an original specimen given me by Mr. Broome.—Entirely white. Pileus hemispherical, at length sulcate, clothed, as well as the stem and gills, with sparkling, glandular pubescence; stem filiform, slightly dilated and hairy at the base; gills adnate, broad, triangular--four to nine.

OMPHALIA.

514. Agaricus atropunctus, *Pers.* Haw Wood, Oct. 1879.

* Agaricus fibula, var. Swartzii, *Fr.* Leigh Wood, July „

This is evidently the plant described by Fries, but is so much like his figure of Ag. setipes as to make it doubtful whether they are not the same species, especially as he remarks that the latter is "too near" to Ag. fibula.

PLUTEUS.

515. Agaricus nanus, *Pers.* Stapleton Park, July, 1879.

„ var. lutescens. „ „ Sept. „

ENTOLOMA.

516. Agaricus sericellus, *Fr.* Leigh Down, Sept. „

CLAUDOPUS.

517. Agaricus euosmus, *Berk.* Glen Froome, May „

LEPTONIA.

518. Agaricus euchrous, *Pers.* Haw Wood, Oct. „

NOLANEA.

519. Agaricus pascuus, *Pers.* Leigh Down, May „

INOCYBE.

520. Agaricus fastigiatus, *Schaeff.* Stapleton Park, July „

521. „ geophyllus, *var.* lateritius. Leigh Wood, „ „

522. „ scabellus, *Fr.* Durdham Down, Sept. „

HEBELOMA.

523. Agaricus longicaudus, *Pers.* Leigh Down, „ „

CREPIDOTUS.

524. Agaricus mollis, *Schaeff.* Leigh Wood, July, 1878.

525. „ rubi, *Berk.* Brockley Coombe „ 1879.

HYPHOLOMA.

526. Agaricus sublateritius, *Schaeff.* Stapleton Park, Nov. „

The plant referred to this species in Part I. is Ag. epixanthus, *Fr.*

527. Agaricus capnoides, *Fr.* Tyntesfield, Nov. „

* „ epixanthus, *Fr.* Sandy Lane, Aug. 1877.

PSILOCYBE

528. Agaricus cernuus, *Müll.* Stapleton Park, Sep., 1879.

529. Cortinarius (Phlegmacium) largus, *Fr.*	Leigh Down,	Oct.	1879,

This fine species was exhibited at the Hereford Fungus Meeting as new to Britain, about a fortnight before I found my specimens.

530. Cortinarius (Myxacium) Riederi, *Fr.*	Leigh Down,	Sep.	1879.

New to Britain. My specimens were named by Dr. Quelet at the Hereford Fungus Meeting.

531. Cortinarius (Telamonia) torvus, *Fr.*	Leigh Do.	Oct.	"
* " " paleaceus, *Fr.*	" "	"	"

This plant has been known for several years, but has only just been identified as the above species. It appears in Part II. as *Cort. diabolicus*, which is, therefore, incorrect.

532. Cortinarius (Hydrocybe) acutus, *Fr.*	Glen Froome,	Nov.	1879.
533. Hygrophorus eburneus, *Fr.*	Stapleton Park,	Oct.	"
534. " russocoriaceus, *B. & Br.*	Leigh Down,	Nov.	"
535. Hygrophorus puniceus, *Fr.*	Clifton Down,	Oct.	"
536. Lactarius blennius, *Fr.*	Stapleton Park,	Sep.	"
537. Russula furcata, *Fr.*	" "	"	"
* " Queletii, *Fr.*	Near Failand,	Nov.	1877,

The plant referred to. *R. rubra* in Part I. proves to be this species.

538. Russula emetica, *Fr.*	Stapleton Park,	Sep.	1879.
539. Cantharellus cupulatus, *Pers.*	Tyntesfield,	Nov.	"
540. Marasmius foetidus, *Fr.*	Haw Wood,	Oct.	"
541. " androsaceus, *Fr.*	Leigh Wood,	July	"
542. Boletus elegans, *Schum.*	Tyntesfield,	"	"
543. Polyporus squamosus, *Fr.*	Shirehampton Park,	June,	1879.
544. " chioneus, *Fr.*	Leigh Wood,	Nov.	"
545. " fraxineus, *Fr.*	Shirehampton Park,	June,	1879.

546. Trametes suaveolens, *Fr.* Henbury, Oct. 1879.

547. „ serpens, *Fr.* Ashton, Sep. „

(On pine bark.)

548. „ Stephensii, *B. & Br.* Leigh Wood, Oct. „

549. Daedalea unicolor, *Fr.* Henbury, „ „

550. Hydnum ferruginosum, *Fr.* Stapleton Park, July „

551. „ udum, *Fr.* „ „ „ „

552. „ farinaceum, *Pers.* Leigh Wood, Dec. 1877.

553. „ niveum, *Pers.* „ „ Nov. 1879.

* Thelephora laciniata, *Pers.* Leigh Down, Oct. „

A small specimen was referred to *T. mollissima* in Part II., which, on comparison, proves to be the present species.

554. Phlebia vaga, *Fr.* Haw Wood, Oct. 1879.

555. Corticium incarnatum, *Fr.* Leigh Wood, May, 1880.

556. Clavaria abietina, *Pers.* Tyntesfield, Nov. 1879.

557. „ juncea, *Fr.* Leigh Down, Oct. „

558. Typhula erythropus, *Desm.* Leigh Wood, „ „

559. Tremella epigaea, *B. & Br.* „ „ „ „

560. Octaviana compacta, *Tul.* „ (C.E. Broome, Esq.),„

561. Hymenogaster vulgaris, *Tul.* „ „ „ „

562. „ tener, *Berk.* „ „ „ „

The following is a list of all the species of *Myxomycetes* which I have met with in this district, arranged according to the method of Rostafinski. It is impossible to determine these plants correctly without attending to the microscopical characters which he gives ; *Didymium nigripes, Fr. D. hemisphaericum, Fr. D. farinaceum, Fr. Stemonitis typhoides, D.C. Trichia turbinata, With. T. chrysosperma, D.C.* and *Licea cylindrica, Fr.* must therefore be erased from the former lists.

* Badhamia hyalina, *Pers.* Leigh Wood, Apr. 1877.

* „ utricularis, *Bull.* Stapleton Park, Nov. 1878.

* Physarum cinereum, *Batsch.* Ashley Hill, Apr. 1879.

563. „ leucophaeum, *Fr.* Clifton, May, 1878.

564. Fuligo varians, *Sommf.* var *a.* Stapleton Park,

ecorticata, var. B. strata floccosa. Autumn, 1879.

565.	Craterium minutum, *Leers.*	Clifton Down,	Oct. 1876.
566.	Leocarpus fragilis, *Dicks.*	Leigh Wood	" "
*	Tilmadoche nutans, *Pers.*	" "	Apr. 1878.
567.	" mutabilis, *Rtfki.*	Tyntesfield,	July, 1879.
*	Didymium squamulosum, *A.&S.*	Westbury,	Mar. 1877
*	Spumaria alba, *Bull.*	Leigh Woods,	Oct. 1878.
*	Comatricha Friesiana, *D. By.*		
	var. *a.* obovata.	" "	Jan. "
	var. B oblonga.	Brockley Coombe,	1878.
*	Stemonitis fusca. *Roth.*	Leigh Wood,	May, 1878.
*	Brefeldia maxima, *Fr.*	Shirehampton Park,	Nov. "
*	Enerthenema papillata, *Pers.*	Leigh Wood,	Spring, "
*	Clathroptychium rugulosum, *Wall.*	" "	Dec. 1877.
568	Dictydium cernuum, *Pers.*	Stapleton Park,	July, 1879.
*	Cribaria intricata, *Schrad?*	Leigh Wood,	" 1877.
*	Reticularia lycoperdon, *Bull.*	" "	April "
*	Cornuvia metallica, *B. & Br.*	" "	" "
*	Arcyria punicea, *Pers.*	Stapleton Park,	Dec. 1878.
569.	" pomiformis, *Roth.*	Leigh Wood	June, 1879.
570.	" cinerea, *Bull.*	" "	" "
571.	" incarnata, *Pers.*	" "	" "
*	" nutans, *Bull.*	" "	July, 1878.
*	Lycogala epidendrum, *Bux.*	" "	Dec. 1877.
*	Trichia fallax, *Pers.*	Leigh Wood,	Nov. 1878.
*	" varia, *Pers.* var. genuina,	Stapleton Park,	Dec. "
572.	" scabra, *Rost.*	" "	" "

The *Trichia* from Leigh Wood, referred to *T. chrysosperma* in Part II., is certainly not that species, nor does it agree well with T. scabra ; the elaters are narrower and not echinulate, and the warted spores are slightly larger.

573.	Hemiarcyria rubiformis, *Pers.*	Stapleton Park,	Sep. 1879.

574.	Crucibulum vulgare, *Tul.*	Abbot's Leigh,	Apr. 1880.
575.	Phoma concentricum, *Desm.*	Cotham (A. Leipner, Esq.)	Apr. 1880.
576.	Dothiora sphaeroides, *Fr.*	Leigh Wood	„ 1879.
577.	Diplodia vulgaris, *Lev.*	Glen Froome,	May, 1878.
578.	„ herbarum, *Lev.*	The Avon,	Mar. 1880.
579.	Hendersonia corni, *Fckl.*	The Gully,	Feb. „
580.	Discosea alnea, *Lib.*	Leigh Down,	Oct. 1879.
581.	Discella microsperma, *B. & Br.*	The Gully,	Feb. 1880.
582.	Coryneum microstictum, *B & Br.*	„	„ „
583.	Dictyosporium elegans, *Corda.*	Leigh Wood,	Apr. 1879.
584.	Puccinia arundinacea, *Hedw.*	The Avon,	„ 1880.
585.	„ polygonorum, *Link.*	Ashton,	Sep. 1879.
586.	Coleosporium rhinanthacearum, *Lev.*	Durdham Down,	July, 1878.
587.	Melampsora betulina *Desm.* (winter spores).	Leigh Wood,	Nov. 1879.
588	Aecidium rubellum, *Pers.*	The Avon,	May, 1880.
589.	Pachnocybe subulata, *Berk.*	Leigh Wood,	July, 1879.
590.	Helminthosporium subulatum, *Nees.*	„ „	Dec. 1877.
591.	„ velutinum, *Link.*	Abbot's Leigh,	Apr. 1880.
592.	„ delicatulum *Berk.*	West Town,	May, 1879.
593.	Macrosporium concinnum, *Berk,*	The Gully,	Feb. 1880.
594.	Gonatosporium puccinioides, *Corda.*	The Avon,	Mar. „
595.	Aspergillus virens, *Link.*	Leigh Wood,	1878.
596.	Fusidium flavovirens, *Fr.*	„ „	Oct. 1879.
597.	Sepedonium chrysospermum, *Link.*	Leigh Down,	„ „
598.	Pilacre Petersii, *B. & Curt.*	Tyntesfield,	Nov. „

599.	Sphaerotheca pannosa, *Lev.*	Clifton Down, Summer, 1878.
600.	Cephalotheca sulphurea, *Fckl.*	Henbury, (C. H. Sp. Perceval, Esq.) Oct. 1879.
601.	Morchella crassipes, *Pers.*	Brockley Coombe, May, 1879.
602.	Vibrissea turbinata, *Ph. in MS.*	Abbot's Leigh, Apr. 1880.
603.	Geoglossum glabrum, *P.*	Tyntesfield, Nov., 1879.
604.	„ hirsutum, *P.*	„ „ „
605.	Peziza macropus, *Pers.*	„ July, „
606.	„ reticulata, *Grev.*	Brockley Coombe, May, „
607.	„ succosa, *Berk.*	Leigh Woods, Sep., „ Haw Wood, Oct., „
608.	„ vesiculosa, *Bull.*	Leigh Down, May, „
609.	„ cupularis, *L.*	Brockley Coombe, „
610.	„ granulata, *Bull.*	Shirehampton Park, June, „
611.	„ (Humaria) misturae, *Phillips.* n.s.	Cotham (A. Leipner, Esq.) Apr., 1880.

Crowded or scattered, sessile, concave when dry, applanate when moist, submarginate, chestnut-brown, glabrous; asci cylindraceo-clavate; sporidia 8, subglobose, smooth, with one large nucleus, ·014 – ·016 × ·011 – ·012 m.m.; paraphyses from one to six times branched, summits proliferously pyriform, or moniliform, or only slightly enlarged.

On a mixture of lime and cow-dung spread on apple trees.

The cups are ½ to 3 m.m. across; the paraphyses are remarkable for their proliferous growth. The cells of the exterior of the cup are small, and oblong rather than globose.

This will be published by Mr. Phillips in his next fasciculus of *Elvellacei Britannici.*

612.	Peziza umbrata, *Fr.*	Leigh Wood, July, 1879.
613.	„ bicolor, *Bull.*	Brockley Coombe, May, „
614.	„ cerina, *P.*	Stapleton Park, June, „

615. „ Schumacheri, *var.* plumbea, *Fr.* Near Brockley Coombe, May, 1879.

616. „ brunneola, *Desm.* Brockley Coombe, May, „

On beech mast and leaves. Mr. Phillips, to whom I am indebted for much valuable assistance, tells me that this *Peziza* has hitherto been met with only on oak leaves. I also found it on beech mast, near Rouen, last year.

617. Peziza trichodea, *Phillips*, Clifton Down, Oct., 1879.

618. „ solfatera, *C. & E.* „ „ July, „

New Jersey Fungi, Grevillea, vii., p. 7. On pine leaves. New to Britain.

619. Peziza pellita, *Pers.* Brockley Coombe, May, „

On beech mast. New to Britain.

620. Peziza aspidiicola, *B. & Br.* Leigh Down, June, „

On dead stems of *Pteris aquilina.*

621. Peziza (Dasy. Sess.) araneo-cincta *Phillips*, N.S. „ „ Autumn, 1879.

Scattered, minute, sessile, concave, thin, pale yellow, margin fringed with long, slender, flexuous, pointed, white hairs ; asci broadly clavate ; sporidia 8, biseriate, narrowly fusiform, acutely pointed, ·01 – ·013 × ·001 – ·0015 m.m.

On decayed birch leaves.

Cups ·2 – ·3 m.m. across. The hairs are without septa, and so delicate that they are diffluent in water, with only slight pressure.

This will be published by Mr. Phillips in his next fasciculus of Elvellacei Britannici.

622. Peziza domestica, *Sow.* Clifton, Feb., 1880.

On wall paper in a house in which a cistern had overflowed about a fortnight previously.

623. Peziza vinosa, *A. & S.* Leigh Wood, Aug., 1879.

624. „ erumpens, *Grev.* „ „ May, „

625. „ atrata. *Pers.* „ „ June, „

626. „ inflatula, *Karst.* { Leigh Wood, 1878. Stapleton Park, June, 1879.

New to Britain.

627. Peziza punctoidea, *Karst* Portbury, June, „

628.	Peziza pulla, *Ph. & K.*, *Belonidium pullum*, *Grevillea*, vi., p. 75.	The Avon,	May, 1880.
629.	Helotium aeruginosum, *Fr.*	Leigh Wood,	May, „
630.	„ citrinum, *Fr.*	Haw Wood,	Oct., 1879.
631.	„ pruinosum, *Jerd.*	Leigh Wood,	Feb., 1880.
632.	„ epiphyllum, *Fr.*	Leigh Down,	Oct., 1879.
633.	Patellaria atrata, *Fr.*	Nailsea,	July, „
634.	„ proxima, *B. & Br.*	Near the Avon,	Nov., „
635.	„ olivacea, *Batsch.*	Stapleton Park,	June, „
636.	„ lignyota, *Fr.*	Leigh Wood,	Apr., 1877.
637.	Tympanis fraxini, *Schm.*	„ „	Feb., 1880.
638.	Dermatea dryina, *C.*	„ „	Dec., 1878.
639.	Ascobolus furfuraceus, *Pers.*	Stapleton Park,	Apr, 1880.
640.	„ granuliformis, *Crouan*,	„ „	„ „
641.	„ (Thecotheus) Pelletièri, *Crouan.*	Clifton,	Mar., „

This species appeared under a bell-glass on soil containing a small *Coprinus*, which had been brought from Glen Froome, in the autumn of last year.

642.	Ascobolus (Ascophanus) lacteus, *C. & Ph.*	Stapleton Park,	Apr. 1879.
643.	Stictis versicolor, *Fr.*	Leigh Wood,	May, 1880.
644.	Hydnobolites cerebriformis, *Tul.*	„ „	Oct. 1879.
645.	Hysterium angustatum, *A. & S.*	Durdham Down,	Mar. „
646.	Nectria episphaeria, *Fr.*	Leigh Wood,	Apr. „
647.	Xylaria digitata, *Grev.*	Stapleton Park,	June, „
648.	Eutypa Acharii, *Tul. ?*	Beggars' Bush Lane,	Feb. 1878
649.	„ scabrosa, *Fckl.*	Leigh Wood,	Apr. 1879.
650.	Diaporthe spiculosa, *Pers.*	Portbury,	June, „
651.	„ scobina, *Nke.*	Near Brockley Coombe,	May, 1879.

652.	Diaporthe pantherina, *Berk.*	Leigh Wood,	Apr.	1879.
653.	Diatrype aspera, *Fr.*	Shirehampton Park,	Jan.	1878.
654.	„ verrucaeformis, *Fr.*	Leigh Wood,	Feb.	1877.
655.	„ angulata, *Fr.*	Stapleton Park,	Mar.	1880.
656.	„ ferruginea, *Fr.*	Leigh Wood,	Jan.	„
657.	Melanconis chrysostoma, *Tul.*	„ „	Mar.	„
658.	Valsa controversa, *Fr.*	„ „	Jan.	„
659.	„ ceratophora, *Tul.*	„ „	„	„
660.	„ ambiens, *Fr.*	The Gully,	Feb.	„
661.	„ quaternata, *Fr.*	Stapleton Park,	Mar.	„
662.	„ leiphemia, *Fr.*	Leigh Wood,	Jan.	„
663.	„ circumscripta, *Mont.*	Near the Avon,	Mar.	„
664.	Massaria siparia, *Tul.*	Leigh Wood,	Feb.	1877.
665.	Ceratostoma ampullasca, *Cooke.*	„ „		„
666.	Byssosphaeria aquila, *Fr.*	Shirehampton,	June,	1879.
667.	Psilosphaeria pulveracea, *Ehr.*	Stapleton Park,	July,	„
668.	Lasiosphaeria ovina, *Pers.*	Leigh Wood,	Apr.	„
669.	Sordaria coprophila, *Fr.*	Stapleton Park,	„	„
670.	„ platyspora, *Ph. & P.*	Leigh Down,	May	„
671.	Sporormia intermedia, *Awd.*	„ „	Apr.	„
672.	Conisphaeria pertusa, *Pers.*	Sandy Lane,	May,	1878.
673.	Xylosphaeria melanotes, *B & Br.* On a willow stick.	Leigh Wood,	Mar.	1880.
674.	Sphaeria fraxinicola, *Curr.*	Brockley Coombe,	May,	1879.
675.	„ millepunctata, *Grev.*	Leigh Wood,	Apr.	1878.
676.	„ salicella, *Fr.*	Near Brockley Coombe,	May,	1878.
677.	„ appendiculosa, *B. & Br.*	Leigh Road,	Apr.	1880.
678.	„ palustris, *B. & Br.*	The Avon,	May,	1880.
679.	„ ulnaspora, *Cooke.*	West Town,	„	1879.
680.	„ agnita, *Desm.*	The Avon,	„	1880.

681.	Sphaeria complanata, *Tode.*	Shirehampton Park, June, 1879.
682.	„ nigrans, *Desm.*	Portbury, „ „
683.	„ tosta, *B. & Br.*	Coombe Dingle, May, „
684.	„ infectoria, *Fckl.*	The Avon, Mar. 1880.
685.	Sphaerella oblivia, *Cooke.*	Brockley Coombe, May, 1879.
686.	„ latebrosa, *Cooke.*	Leigh Wood, „ „
687.	„ carpinea, *Fr.*	„ „ „ „
688.	„ errabunda, *Gonn & Rabh.*	Brintry, „ „

On beech leaves. New to Britain.

689.	Gnomonia setacea, *Pers. var.* petiolae.	Leigh Wood, May, „

The Pomarine Skua.

By H. CHARBONNIER.

Six specimens of Lestris Pomatorhinus (Tem.)—The Pomarine, or Pomatorine, Skua, obtained in November, 1879, were exhibited.

No. 1, shot at the New Passage.
2 & 3, „ Clevedon.
4 „ 5, „ Filey.
6 „ Scarborough.

Several other specimens were obtained in the neighbourhood, one at Chew Magna and two more at Clevedon. The plumage was singularly varied, no two being alike. Nos. 5 and 6 were birds of the year, in the barred stage, and with the centre tail feathers projecting half-an-inch beyond the others; Nos. 2, 3, and 4 were old birds, with more, or less, of white on the breast and pale yellow on the sides of the head. The centre tail feathers were unfortunately broken off short in these three specimens. No. 1 was in the intermediate stage, upper parts brown, throat, breast, and tail coverts, white barred with brown, a faint tinge of yellow on the sides of the head, and the centre tail feathers *two and-a-half inches* longer than the others.

L. Pomatorhinus closely resembles L. Richardsonii in some of its stages, but can always be distinguished on accurate measurement by its superior size. Like the rest of the Skuas these birds are predaceous in habit, living by plundering the Gulls and other birds of their prey. They are rare in England; and I have never heard of their occurrence within our district before. They are

possessed of great powers of flight, and range over a vast area, their utmost northern range is 82° N. lat., from thence they extend as far south as Cape York, in Australia, Alaska and Pennsylvania, in America, they also occur in Africa and in Japan. Middendorf found them breeding in Siberia, and they are also believed to breed in Greenland.

It is very singular that a large proportion of the specimens obtained had the centre tail feathers broken, and broken *shorter*, in some cases, by an inch or more than the other tail feathers, which latter were quite perfect. The only way I can account for this is by supposing that these feathers are broken by the tail being violently rubbed on the ground *when fully expanded*. The outline of the tail would then be a semi-circle, and the central radii of the arc could then be rubbed or broken off *shorter* than the rest, without these latter being injured. I may add that I have seen feathers so broken in poultry.

Rainfall at Clifton in 1879.

BY GEORGE F. BURDER, M.D., F.M.S.

TABLE OF RAINFALL.

	1879.	Average of 25 years.	Departure from Average.	Greatest Fall in 24 hours.		Number of days on which ·01 in. or more fell.
				Depth.	Date.	
	Inches.	Inches.	Inches.	Inches.		
January	4·307	3·462	+0·845	1·571	1st	11
February... ...	3·921	2·120	+1·801	0·540	20th	22
March	1·102	2·247	−1·145	0·242	30th	13
April	2·863	2·057	+0·806	0·555	23rd	14
May	3·218	2·284	+0·934	1·055	28th	18
June	5·145	2·441	+2·704	0·616	30th	24
July...	3·669	2·783	+0·886	0·603	19th	20
August	7·319	3·404	+3·915	1·243	16th	21
September ...	3.906	3·414	+0·492	0·661	8th	19
October	1·276	3·646	−2·370	0·305	19th	11
November ...	0·586	2·749	−2·163	0·180	11th	8
December ...	1·345	2·711	−1·366	0·541	30th	8
Year	38·657	33·319	+5·338	1·571	Jan. 1st.	189

REMARKS.—The year 1879 was characterised by a total rainfall considerably in excess of the average, notwithstanding that the three last months of the year were remarkably dry. The extraordinary succession of rainy years with which we have been visited since 1872, will be seen by a reference to the following table:

RAINFALL OF EIGHT YEARS.

Year.	Rainfall.	Departure from Average of 25 years.
	Inches.	Inches.
1872...	42·366	+ 9·047
1873...	32·069	− 1·250
1874...	35·248	+ 1·929
1875...	44·047	+ 10·728
1876...	42·415	+ 9·096
1877...	38·230	+ 4·911
1878...	38·019	+ 4·700
1879...	38·657	+ 5·338
Mean of 8 years.	38·881	+ 5·562

It will be noticed that of the last eight years one only has shown a deficiency, all the rest an excess. The deficiency in 1873 was trifling, the excess in most of the other years was large. The largest excess was in 1875, which was the wettest year ever observed at this station the total downfall being over 44 inches. In 1872 and 1876 the fall, was also exceedingly large, each of those years yielding upwards of 42 inches of rain. For the whole period of eight years the annual mean has been nearly 39 inches, and the mean annual excess, more than five and a half inches.

The rainiest month in 1879 was August, with 7·319 inches--a monthly total which has only twice been exceeded within the period of observation. The driest month was November, with 0·586 inch. October, November, and December, were all very dry, the aggregate of the three months being no more than 3·207 inches—a quantity much less than has ever before been recorded in the same three months.

The heaviest diurnal fall in 1879 was on the 1st of January, when the rain and melted snow measured together 1.571 inches.

The principal snow-storm of the year occurred on the 7th of January, when the average depth of snow was 5 inches, and drifts were formed in exposed situations to a depth of 3 or 4 feet.

REPORT.

THE Council of the Bristol Naturalists' Society, in presenting their Annual Report, cannot but refer, in the first place, to the heavy loss the Society has sustained by the recent death of its president, Dr. Henry Edward Fripp. Dr. Fripp had been connected with the Society from its commencement, and had been president since the year 1876, when he was elected to that office in succession to the late Mr. William Sanders. He died from an attack of apoplexy on the 23rd of March, after a few hours' illness. Dr. Fripp was born in 1816, and passed through his curriculum of medical education at the Bristol Medical School, being a pupil of the late Dr. Symonds, at the General Hospital. Becoming a member of the Royal College of Surgeons in 1838, he began practice in Wales as medical officer to the iron works at Yniscedwyn, near Swansea. Shortly afterwards he went to Germany as medical officer to the iron works at Nisterthal, in the Duchy of Nassau. By nature a mechanical genius, Dr. Fripp took so great an interest in these works, that, in addition to his professional responsibilities, at the request of the directors, he accepted the office of chief engineer, and held his post till 1848, when the works were closed owing to disturbances consequent upon the unsettled state of the political atmosphere. After this, Dr. Fripp spent some years on the Continent, in medical and scientific study and research, and in 1855 took the degree of M.D. at Würtzburg. Returning to England, he obtained, in 1856, the diploma of membership of the Royal College of Physicians of London, and settled in Clifton as a physician. In 1859 he was elected physician to the Bristol General Hospital, and in 1873, on retiring from the more active duties, he was appointed consulting physician to that institution.

He occupied the chair of physiology in the Bristol Medical School from 1857 to 1869. Dr. Fripp was an industrious worker in science, both medical and general. The published proceedings of our own Society contain many valuable contributions from his pen, several of them relating to microscopy, and others to insect anatomy. The Bristol Microscopical Society also benefited by his labours, his knowledge of the microscope, both in regard to its theory and its practical use, being most intimate and complete. During the year 1878-79, he was president of the Bristol Medico-Chirurgical Society, and his inaugural address, which was published by request, was a learned dissertation on "The Doctrine of Contagium Vivum in its relation to Parasitic Disease." Dr. Fripp was an ardent lover of music, and was himself an accomplished musician. As illustrating both his musical and mechanical skill, it may be mentioned he possessed an organ which he had himself built. As a physician, Dr. Fripp was held in the highest regard both by the members of his own profession and by his patients. Of sound judgment, fertile in resources, and full of tender sympathy, he won both confidence and love. Passing from this brief record of the life and work of our lamented president, the Council regret to have to report the removal from the neighbourhood of some valued members. Professor Letts, F.R.S.E., has been appointed to the chair of chemistry at Queen's College, Belfast, and Dr. Tildon (whom the council congratulate on his newly-acquired distinction of F.R.S.) has accepted a similar appointment at Birmingham. Mr. J. Norman Collie, who had also given promise of good service to the Society, has followed Prof. Letts to Belfast. Altogether the losses to the society by resignation, removal, or death have numbered, during the year, sixteen; but as seventeen new members have joined, our numerical strength has been somewhat more than maintained. The total number of members is at present 169. During the past session, the General and Sectional Meetings of the Society have been held as usual.

The attendance at the General Meetings has been less numerous than could be wished, averaging nineteen members and nine visitors. In consequence of the unsettled state of the weather, it was not thought expedient to organise any general excursion last summer. The Botanical Section, however, pursued their work with little interruption, taking weekly rambles during the greater part of the season, and working up the botany of the district with a view to the publication of a local "Flora" The Council are pleased to report that, by an arrangement with the Council of the Museum and Library, a number of additional shelves have been secured for the Society's Library, the books of which will now, it is hoped, be more accessible to members than they have hitherto been. The Financial Statement, which the Council presents herewith, shows the finances of the Society to be in a satisfactory condition. Owing to the exertions of the honorary treasurer in collecting arrears of subscriptions, the balance in hand is considerably larger than at the corresponding period of last year.

CAPITAL ACCOUNT.

		£ s. d.
1878. May 22.	By Cash Invested in Hand and Hand Building Society	£10 0 0

GENERAL ACCOUNT.

Date		£ s. d.	Date		£ s. d.
1879.	To Balance brought forward	17 0 8	1879. June 26.	By Museum Custodian	1 1 0
	,, Subscriptions to 1st May, 1880	64 10 0	,, ,,	,, Donation to Museum	10 10 0
	,, Arrears paid	25 15 0	Aug. 20.	,, Hemmons, Proceedings	40 0 0
	,, Interest on Investment	0 10 0	1880. Jan.	,, Morgan, Stationery	1 0 6
				,, Hemmons, Notices	5 11 0
			April	,, Postage, Hon. Treas	0 10 0
			Expenses of Hon. Sec.	,, Notices—General and Council Meetings	3 5 2
				,, Postage of Proceedings	2 15 3
				,, Post Cards and Stamps	1 10 4
				,, Stationery	0 6 4
				,, Printing	0 8 6
				,, Carriage for Book Parcel	0 7 8
				,, Assistant Secretary	8 0 0
				,, Balance	32 9 11
		£107 15 8			£107 15 8

	£ s. d.
Arrears for 1879	14 5 0
Previous Arrears	1 10 0
	£15 15 0

LIBRARY ACCOUNT.

Date		£ s. d.	Date		£ s. d.
	To Balance brought forward	12 5 4	1879. Nov. 22.	By Zoological Record	1 0 0
	,, Donation to 1st May, 1880	2 0 6		,, New Doors to Library	2 5 6
	,, Entrance Fees	2 15 0		,, Kerslake, Binding	2 9 0
				,, Balance	11 6 4
		£17 0 10			£17 0 10

DONATIONS TO THE LIBRARY.

	£ s. d.
Braikenridge, Rev. J. W.	1 0 0
Derham, James	0 2 6
Derham, Samuel	0 2 6
Derham, Walter	0 2 6
Stuckey, Samuel	0 2 6
Thomas, Herbert	0 10 6
	£2 0 6

Examined the above Account, and found the same correct.

F. V. JACQUES,
ALFRED E. HUDD.

6th May, 1880.

REPORTS OF MEETINGS.

Geological Section.

Last year, owing to the very wet season, nearly all the excursions fell through. Only one was actually taken, which was to Dundry, on July 9th, but, unfortunately, the day proved very boisterous and rainy, so that but little work was done.

Report of Entomological Section, 1879.

During the summer, owing to the long continued wet weather, only one excursion was taken, to Brockley, in June.

At the November Meeting of the Section Mr. HUDD exhibited a box of *Lepidoptera* taken near Stroud, by the REV. R. S. GATES, which contained, among other things, three species not recorded as having occurred in the Bristol District—*viz. Lithosia Aureola, Cleora Glabraria, and Cucullia Lychnitis.*

At the December Meeting Mr. ROSS exhibited fine varieties of *Polyomatus Corydon*, and a very singular hermaphrodite specimen of *P. Ægon*, the wings being distinctly of the male and female forms on opposite sides.

Mr. FICKLIN also exhibited a number of specimens of a new species of the *Genus Eupithesia* bred from *Larva* captured by himself in North Devon.

At the January Meeting of the Section Mr. GRIGG exhibited a box containing a fine set of *Drepana sicula*, with living *pupa*, and drawings of the *larva*, and read a short paper showing that the life history of this interesting species had been now worked out. He also exhibited a specimen of *Heliothis Scutosa*, interesting, not only on account of its excessive rarity in England, but also from having been captured in the borders of the Bristol District.

Many interesting exhibitions of foreign and exotic *Lepidoptera and Coleoptera* were also shown at the different meetings of the Sections.

GEORGE HARDING, *Hon. Sec.*

Annual Report of the Botanical Section of the Bristol Naturalists' Society, 1879.

The prevalence of wet weather during the spring and summer caused the failure of much of the out-door work undertaken by the Section, and some of the weekly excursions were abandoned on this account. Good progress has been made however in preparing the MSS. of the *Flora* of the Bristol Coal-Fields.

In response to circular invitations issued by the Hon. Sec., a great deal of valuable material in notes and records has been furnished by the members of the Section, and much, also, by naturalists in the outlying portions of the district. This is now in process of examination and arrangement.

The Sectional Meetings during the winter months have chiefly been devoted to the study of Structural Botany, under the able direction of the President.

Physical and Chemical Section.

The following communications have been made to the Section during the year :—

Oct. 28th, 1879.

Dr. G. S. Thomson.—" On Hughes' Induction Balance."

W. L. Carpenter, Esq., B.A., B.Sc.—" Some Observations on the Teaching of Physics and Chemistry in Canada and the United States."

Dec. 2nd, 1879.

Dr. G. S. Thomson—" On Crossley's Carbon Transmitter."

Francis J. Fry, Esq.—"On Mr. Crooke's Recent Researches on Radiant Matter."

Jan. 29th.

Mr. A. M. Worthington, M.A.—" The Splash of a Drop."

April 27th.

Professor W. Ramsay, Ph.D., F.R.S.E.—" On the Cohesion of Liquids."

Dr. G S. Thomson.—" On Balmain's Luminous Paint."

Professor P. S. Thompson, D.Sc.—" On the Audiphone."

List of Societies to which the Proceedings of the Bristol Naturalists' Society are sent.

Barrow Naturalists' Field Club.
Bath Natural History and Antiquarian Field Club.
Belfast Naturalists' Field Club.
Birmingham Natural History and Microscopical Society.
Calcutta, Geological Survey of India.
Cardiff Naturalists' Society.
Chester Natural Science Society.
Clifton College Scientific Society.
Cotteswold Naturalists' Field Club.
Dudley and Midland Geological Society and Field Club.
Edinburgh Geological Society.
——— Botanical Society.
Epping Forest and County of Essex Naturalists' Field Club.
Falmouth, Cornwall Royal Polytechnic Society.
Glasgow Geological Society.
——— Natural History Society.
——— Philosophical Society,
Liverpool Geological Society.
——— Literary and Philosophical Society.
London, British Museum Library.
——— Geologists' Association
——— Queckett Microscopical Club.
——— Royal Microscopical Society.
Manchester Geological Society.
Manchester Scientific Students' Association.
——— Literary and Philoscopical Society.
Marlborough College Natural History Society.
Norwich, Norkfolk, and Norwich Naturalists' Society.
Penzance, Royal Cornwall Geological Society.
Plymouth Institution and Devon and Cornwall Natural History Society.
Redruth Miners' Association of Devon and Cornwall.
Rugby School Natural History Society.
Taunton, Somersetshire Natural History and Archæological Society.

Torquay Natural History Society.
Warwick Natural History and Archæological Field Club.
Watford Natural History Society, and Hertfordshire Field Club.
Wiltshire Archæological and Natural History Society.
Winchester and Hants Literary and Scientific Society.
Woolhope Natural History Field Club.
Yorkshire Naturalists' Union.

FRANCE.

Société D'Etudes Scientifiques, Palais-des-Arts, Lyon.

NORWAY.

Det Kongelige Norsk Universite i Christiania.

GERMANY.

Cassel, Verein für Natur Kunde.
Oberhessische Gessellschaft für Natur und Heilkunde, Giessen.

SWITZERLAND.

Lausanne, Societé Vaudoise des Sciences Naturelles.

UNITED STATES.

Boston (Mass.) Natural History Society.
Salem Mass., U.S., Essex Institute.
Washington Smithsonian Institution.
——United States Geological Survey of the Territories
Philadelphia Academy of Natural Sciences

NEW SERIES, Vol. III., Part II. (1880). Price 2s. 6d.

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NOTE.—The chart accompanying Dr. Burder's paper on the Course of Storms is, unfortunately, not the chart for which application was made to the Chief Signal Officer of the United States. The chart which has been sent, having a certain interest of its own, is made use of, although, referring, as it does, to the American continent alone, it fails to illustrate several of the points indicated in the paper. The reader who may be interested in pursuing the subject, is referred to *Nature*, vol. xxi., p. 304, where he will find published the identical chart upon which the remarks in the paper have been founded.

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NEW SERIES, VOL. III., PART II.

On the Breathing Apparatus of Aquatic Larvæ.

By W. J. FULLER, F.C.S.

THE object of the following Paper is to lay before the Society one or two peculiarities which I have noticed in the breathing apparatus of some aquatic larvæ. The first to be considered are the *Libellulidæ*, and then a short sketch of *Corethra* and *Chironomus* will follow.

The larvæ of the *Libellulidæ* are very interesting creatures, though they are sluggish in their movements; some (*e. g. Æschna* and *Agrion*) perch all day on aquatic plants; others (*e. g. Libellula*) bury themselves in the mud up to their eyes and stay perfectly motionless till some unsuspecting water shrimp or *Daphne* comes swimming near them, when the *labium* (which is formed to work like a man's arm, the shoulder being attached to the chin, and the hand extending over the lower part of the face when at rest) is suddenly extended, and the unfortunate shrimp is caught in the hand-like extremity and conveyed to the mouth.

The larvæ can, however, move moderately fast if frightened, and they do this by drawing water into a sac, which is situated in the caudal extremity of the abdomen, and expelling it by contraction of the abdominal rings, thereby propelling themselves an inch or two forward, and repeating this, they progress with a jerky movement. That this is really the mode of progression may be seen by placing them in a glass of water with a little sand at the bottom, when the effect of the jet from the tail is

easily observed, the sand being spirted up at every movement of the animal.

It is within this sac that the breathing organs of *Æschna*, *Libellula*, and *Calopteryx* are situated, but to study the disposal of them it is necessary that the larva should be dissected. To do this it is best to fix the animal on its back, and open the abdomen all round the lateral seam with curved scissors, taking great care not to injure any of the internal organs in so doing; then turn back the skin and cut it off close to the thorax; having done this, the disposition of the intestines, trachea, and respiratory sac may be observed with the greatest facility.

First, close to the thorax is the stomach, leading into the small intestines, to which are attached the peculiar filamentous bodies which are generally called "Biliary canals"; further on the large intestine, and then the *sphincter ani;* this opens into the breathing sac at its anterior extremity, and all fœcal matter on passing into this sac is instantly discharged at the posterior valve by a rapid contraction of the abdomen, similar to that by which the animal propels itself through the water.

Thus it will be noticed that this sac is not identical with the large intestine, as stated by Dr. Duncan and others, but is supplementary; the real *sphincter ani* being situated at its anterior extremity.

In the case of *Agrion*, however, this sac is altogether wanting, so far as I have been able to observe, and the quick movement which it makes when escaping an enemy, is managed by means of three broad leaf-like appendages situated on the end of the tail; these are spread out, somewhat like a chestnut leaf, and suddenly are brought together backwards, thus acting as paddles in sending the insect through the water; these appendages are strongly keeled, to give them more power of resistance.

If these plates be examined, it will be found that they are filled with *trachea* ramifying over the whole surface, and it is by

means of these *trachea* that the animal breathes, by taking the oxygen from the surrounding water and giving off the carbonic acid gas which has been produced by circulation.

These plates are connected with the tracheal system of the body as follows. As in most other larvæ there is one leading tracheal canal running down either side of the body; this, on arriving at the last segment of the abdomen, splits in two, the lower half passing into the leaf-like plate on that side, and the upper half, together with the upper half of the other side, passing into the upper plate; the third plate being supplied from the lower branch of that side.

Thus there is no real circulation of the air in the trachea; diffusion probably being sufficient to renew the air as fast as it becomes vitiated.

So here we have *Agrion* with three external breathing plates situated on the eleventh segment of the abdomen, and on the ninth there are five small pointed plates, three on the belly and one on either side, which, according to Burmeister, are the seat of the male organs of generation in the perfect insect. I shall call attention to these after speaking of some of the other allied larvæ.

In the case of *Calopteryx* the sac which I mentioned above also occurs; and, on dissecting it, there will be found three plates, similar to those of *Agrion*, within it, affixed to the innermost extremity and surrounding the anal orifice.

The water for aeration is admitted through the valve in the extremity of the abdomen, and is expelled by the flattening of the rings containing the sac.

Thus we have *Calopteryx* with three plates situated internally, but in all other respects similar to those of *Agrion*; that is, they are fixed on the circle surrounding the anus, but the anus is internal.

Libellula has the breathing apparatus still more developed;

like *Calopteryx*, the Branchial plates are enclosed in an internal sac, but the three large plates are replaced by about three hundred much smaller ones, which are arranged most symmetrically in six rows; each row having the appearance of being double, owing to the plates laying first on one side and next on the other, giving to each row very much the appearance of an acacia leaf with its leaflets.

These rows are connected with the general trachea by quite an extensive system of small branches. First, there are two tubes which supply the intestines, &c.; these are connected with the two lower rows of *branchiæ*, each tube running the whole length of a row, and throwing off branches *en route*, but upon the outside of the sac. Then there are the two large trachea running the whole length of the body, and supplying head, legs, and embryo wings; these are connected with the four upper rows of plates, each tube passing down outside two rows of plates and sending out branches to the individual *branchiæ*. These branches, on entering the plates, sub-divide into the minutest threads which entirely fill the space between the thin walls, and thus offer a comparatively enormous surface for aeration.

In *Æschna* the same apparatus is present in all its details, the only difference being in the shape of the plates. This sac is closed by three semicircular plates, closing partly over each other, and situated in the extremity of the abdomen, being protected by five pointed plates which open and close at will, and assist in making the propulsive jet more effectual by concentrating it.

These five pointed plates are situated on the ninth segment of the abdomen, and, on finding this was the case, I wondered considerably what had become of the other two segments, which are present in *Agrion*.

Now, if we return to the above remarks on *Agrion*, it will be

noticed that there are five small, apparently useless points on the ninth segment, and the natural inference will be that the two succeeding segments have been invaginated in *Calopteryx*, carrying the terminal plates with them, thus forming the enclosed sac with the breathing-plates contained in it.

In the case of *Libellula*, the plates have gradually increased in number until they have attained their present profusion, the five points of *Agrion* having become modified into a guard for the valves, and a concentrater for the jet of water used in propulsion.

It may, perhaps, be interesting to state here that, in casting its skin, the larva throws off the external skin of this sac intact, all the numerous plates being distinctly recognizable in the cast-off skin, and still occupying the same position at the lower end of the abdomen.

This fact appears to corroborate the foregoing opinion that the sac with its *branchiæ* in *Æschna*, &c., represents the two terminal segments of *Agrion*.

The Larva of the *Ephemeridæ* are in many respects similar to those of the *Libellulidæ ;* their breathing *branchiæ* are arranged down the sides of the abdomen, two or four gills being present on each segment; these are connected from the two main tracheæ which run down either side of the body, by short tubes running directly into them, and then subdividing into the usual capillary tubes. These gills are constantly waving about in the water, absorbing oxygen, and giving out carbonic acid formed in the body.

In these beautiful creatures the tracheal system may be followed into the most remote points of the body, owing to their transparency, especially when young. Sir John Lubbock states, that *Cloeon* has not these gills when young, and that it breathes by osinosis through the skin itself until the fourth moult, when the gills appear; but still there are no tracheæ till

the next moult. A similarly progressive change may be noticed in the larva of *Corethra plumicornis*, the well-known glass larva. In the larval condition there is no special breathing apparatus, unless the beautiful plumose tail, or the bundles of setæ, are in some way used for that purpose.

It seems, however, far more probable that aeration takes place through the skin itself, or the joints, as in the foregoing instance of *Cloeon*. There are four kidney-shaped air bladders, arranged two at the tail and two near the head of the larva, which are of a tracheal nature, being lined with the ordinary spirally arranged hair; but there is no tracheal tube connecting either of these four with each other, each appearing to be independent of the other, and being probably for the purpose of preserving a balance, and enabling the animal, which has no legs, to maintain a horizontal position when suspended in the water.

When, however, the larva has changed its skin for the last time, before changing to the pupa state, a definite tracheal system may be seen running the whole length of the body, and in front and above the two thoracic air sacs, are two spindle-shaped bodies; but as yet none of these newly developed organs contain air.

After the next moult has taken place the tracheæ are found full of air, and the kidney-shaped air sacs have disappeared, whilst the two spindle-shaped bodies, above mentioned, having been liberated from their confined position, are filled with air, and stand out straight above the pupa, which now assumes an upright position. These floats are not filled by rising to the surface and drawing in the external free air, as is the case with gnat pupæ, but from the trachea, the air absorbed from the water first passing through the body.

I can speak with certainty on this point, as I have seen the larva change to a pupa, and the floats gradually filled, without its once rising to the surface.

It is highly probable that these assist in the breathing, as the large surface exposed to the surrounding fluid would naturally cause a good deal of oxygen to be absorbed through the walls, but I think it is materially assisted by the broad fan-shaped tail, which has a large tracheal tube ramifying through it.

The manner in which these larvæ and pupæ maintain themselves suspended in water is of great consequence to their preservation, for their near relation, the *Chironomus*, which is always either on the surface or at the bottom of the water, is constantly falling a prey to the *Planarians*, which are roving about in search of what they may devour; being unable to swim freely through the water they fail to catch the *Corethra* larvæ or pupæ, which may be kept in the same glass with *Planarians* without chance of injury, whereas the *Chironomus*, as I have frequently found to my discomfiture, immediately falls a prey to them; this is owing to its habit of falling to the bottom of the water, or resting at the top against some weed or the sides of the vessel, according to whether he has his tubes full of air, or empty. In either of these positions it falls an easy prey, and I have no doubt that most other aquatic larvæ are troubled with the same pest, unless they have some means of protecting themselves, such as the case of Caddis worms, a burrow like the *Ephemera*, a means of floating as in *Corethra*, &c., or continually swimming about like *Daphne*.

Thus it will be seen that the breathing apparatus in *Agrion*, *Libellula*, *Ephemera*, and *Corethra*, are used not only as such, but also as the means of locomotion and of protection from their enemies. This beautiful adaptation of means to an end cannot fail to strike the most careless observer, and appears to me a good illustration of the variations which circumstances may produce in any given organ.

On Hearing with Two Ears.

By SILVANUS P. THOMPSON, D.Sc., B.A., F.R.A.S.
(Professor of Experimental Physics in University College, Bristol.)

1.—MAN is provided with two ears, as well as two eyes. If he had not two eyes, it would be almost impossible for him to distinguish the distances and solid forms of objects; for, as Wheatstone showed, the perceptions of solidity and of distance acquired through the eye are due to the fact of our having two eyes; the former of these perceptions having for its starting point the slight differences between the two retinal pictures in the two eyes, the latter being based upon the muscular sensations of the greater or less convergence of the optical axes when viewing near or distant objects, or, as it is sometimes termed, upon binocular parallax. The theory of Binocular Vision was practically complete when the invention of the stereoscope, and of its *reductio-ad-absurdum*, the Pseudoscope, proved the correctness of Wheatstone's theoretical views.

Man has two ears; and whatever view we take of the process of creation, theological or evolutionist, we must admit that the two ears, like the two eyes, serve a purpose which one ear could not serve alone. It has therefore been my endeavour, in a research carried on at intervals during several years, to investigate the functions of the two ears, in the hope of throwing light upon some of the unexplained facts in the perception of sound. These researches in Binaural Audition are therefore analogous in aim to those of Wheatstone in Binocular Vision.

2.—One of the facts in the perception of sound which has never been satisfactorily explained is that of the acoustical

perception of *direction*. A blind-folded man in a perfectly dark room is able to say, with very considerable accuracy, in what direction the source of any sound that may be made in the room is situated. In the open air he has a similar perception of the direction of a sound, but is liable to be deceived by sounds of a certain class. It has been my aim more particularly to bear this matter in mind during my investigations, which have a direct bearing upon it.

The facts which I have brought to light are of the highest importance both for the physicist and the physiologist. I cannot claim, however, to rank either as a physiologist or an anatomist; and the methods of research employed have been purely physical. I will give the results of my investigations as briefly as possible.

3.—*It is possible to produce an "interference" in the perception of sounds.* I prove the existence of this interference by the following simple experiment:—Let two tuning-forks, in unison with one another, be taken, and let one be loaded with a pellet of wax so as to vibrate a little more slowly than the other. When these two tuning-forks are excited by striking or bowing, and placed near one another so that their vibrations are communicated to adjacent masses of air, we have the phenomenon of interference commonly known as "beats." If, now, the sounds of these forks are separately led to the two ears by means of india-rubber tubes the beats are still heard; and they appear to be taking place in the interior of the head. They can be distinguished even when each of the sounds is too feeble to be heard separately, and when every precaution is taken to guard against the actual commingling of the sound waves. They are even heard when the Eustachian tubes of the ears are closed during a catarrh.

4.—*If two simple sounds in unison with one another reach the ears in opposite phases, the resulting sensation instead of being localized in the ears appears to proceed from the back of the head.*

There are several ways of observing this singular subjective phenomenon. (1) The sound of a tuning-fork may be led to the two ears by two tubes whose lengths differ by half the wave-length of the sound employed, so that the vibrations reach the ear in opposite phases. (2) Two tubes, of equal length, leading separately to the ears may have their other ends placed opposite to two adjacent quadrants of the space surrounding a vibrating tuning-fork, in which case also there will be complete opposition of phase in the sounds that reach the ears. (3) While two tubes of equal length lead to the ears, two tuning-forks, tuned to perfect unison, are made to vibrate opposite the respective ends of these tubes, one of the forks being fixed while the other is slowly rotated around its axis. Here the sounds will arrive alternately in complete agreement and complete opposition of phase. (4) Lastly, we may transmit a sound electrically by any telephonic transmitter and receive it by the aid of a pair of Bell Telephones applied to the ears. If these telephones are joined up in the circuit, so that the current can be made to traverse the coils round their magnets, either in the same direction, or in opposite directions (the magnets being set similarly in each) the vibrations of the diaphragms will be either in agreement, or in opposition of phase. When they agree in phase the sounds appear to be localised in the ears, when they are opposed in phase they appear to be localised at the back of the head. In the case of some observers the sensation of any definite localisation fades rapidly away, to be revived again when the difference of phase of the two sounds is altered. These phenomena of "localisation" have been observed many times by persons experimenting with the telephone, and they were independently announced (after the present writer had published them to the British Association) by Sir William Thomson and by Professor Graham Bell. With a microphone and a pair of receiving telephones the effect of localisation is remarkable.

5.—*This localisation of the subjective acoustic "image" is independent of the pitch of the sound.* This is proved for sounds of all degrees of pitch and of every possible complexity of "timbre" by the employment of telephones. If the sounds are transmitted by tubes of india-rubber the localisation is manifested only for *simple* sounds: for complex sounds the difference of length which produces complete opposition of phase for the fundamental sound does not give the same effect for all the upper partial tones.

6.—*This last observation suggests a method for analysing complex sounds without the employment of Resonators.* In fact, by binaural audition, it is possible to recognise a difference between two complex sounds, the separate partial tones of which are present in equal numbers, and of the same pitch and intensity, and which present only differences of *phase.* This proposition, it will be remarked, contradicts the assertion of Helmholtz that the ear cannot distinguish differences of phase. This conclusion, which was drawn from the joint sensations of the ears, is negatived by the phenomena which are observed when the sounds that differ *in phase only* are led *separately* to the two ears.

7.—*When the difference of phase of the two tones thus led to the ears is less than half an undulation, the sensation is only partially localised in the back of the head,* and partly in the ears. The sensation is not simple nor capable of exact description.

8.—*If the difference of phase is complete, but the two sounds of unequal intensity, the "acoustic image," instead of being at the middle of the back of the skull, is nearer to the side of that ear which is receiving the louder sound.* This can be shown by taking tubes of unequal diameters, or with two telephones in which the magnets are not equally strong.

9.—*To binaural audition the consonant intervals appear rough, and the dissonant intervals extremely harsh.* If different simple tones are led to the ear, as c' and e', or c' and g', the effect is disagreeable. The seventh c' b' unendurably grating.

10.—*When two sounds constituting a simple interval are led separately to the ears*, there is no differential resultant-tone ("Tartini's tone"); at least I have never been able to hear one. I am disposed to attribute the unexpected harshness of the ordinary intervals to the absence of this differential tone, which would harmonise the two. It must, however, be added, that if the two tuning-forks used have only a narrow interval, and are capable of producing a clearly distinguishable differential tone, and if they are placed together near a Hughes' Microphone to which two telephones are connected so as to give opposed phases of vibration, then not only will the two primary sounds be heard, but also their differential tone; and they will all be apparently localised at the back of the head.

11.—When a sound reaches an observer from a point right in front of, or behind, or above him, the length of path travelled by the sounds to the two ears is the same for all sounds. But if the source of sound be to right or left of the observer, the sound will reach the one ear a little later than the other, and with a difference of phase depending both on the wave-length of the sound and on the cosine of the angle between the line of the sound and the median plane of the head. Hence it is *possible* that a difference of phase in the ears may suggest to the mind that the sound is coming obliquely.

12.—Since these results were worked out, Prof. Steinhauser has published a theory of Binaural hearing, in which he has worked out on geometrical principles the laws which determine the relative *intensity* with which a sound will reach the two ears when starting from different points. The intensities are equal in the two ears when the source of sound is in the median plane, and is a maximum when in front, a minimum when behind the head; since the ears are set angularly, so as to catch sounds from in front of the head, in planes, which determine, according to Steinhauser, the conditions of best hearing. The operation,

therefore, of finding the direction for the sound—say a lark singing high up in the air—will, according to Steinhauser, be as follows:—first the head is turned horizontally until the sound is equally loud in both ears, then the head is moved up and down until maximum loudness is attained; when the lark will be found in the line of sight. Steinhauser's theory, it will be noted, takes into account no differences of phase, pitch, or timbre, but of intensity only: and it fails to account for the fact that we have, *without moving the head at all*, a very fair sense of the direction of sounds.

13.—To test Steinhauser's theory I have devised a little instrument called the *Pseudophone*, which is, for the ears, what Wheatstone's Pendoscope was for the eyes—an instrument for verifying the laws of perception by means of the illusions which it produces. The *Pseudophone* consists merely of a pair of adjustable reflectors, or flaps, which can be fitted into the ears, and capable of turning round to any required position. By altering the position of the flaps we alter the relative intensities of two sounds as received in the ears; and this can be done without the blindfolded experimenter knowing how the flaps are set. If, for example, the flaps are set to catch sounds from behind, the experimenter will think that he is looking in the direction of sound, when he is looking in precisely the reverse direction. But I find that the instrument fails to give satisfactory illusions with *simple tones*, such as those of tuning-forks, especially when the experiments are made out of doors. I cannot therefore accept Steinhauser's theory without some considerable modifications.

14.—Lord Rayleigh[1] has pointed out that the diffraction of complex sounds round the head will produce the result that tones of different pitch arrive the opposite side of the head to

[1] Transactions of Musical Association, 1876.

that nearest the source of sound with very different intensities. He is disposed, from some careful experiments made on an open lawn with different kinds of sounds, to attribute the perception of the direction of sounds to this inequality produced by diffraction, the brain drawing from the slight differences of the tones received in the two ears an unconscious judgment based on empirical observation. It is undoubtedly a remarkable fact that while the ears can distinguish perfectly well whether the simple tone of a small tuning-fork comes from the right or from the left, they often cannot tell one whether such a sound is immediately in front or immediately behind. Now it is for simple tones that Steinhauser's theory ought to be true if for any; and it is precisely for these that it fails when put into practice in the *Pseudophone*. When the effects of diffraction are such as to be relatively negligible, as for shrill sounds, whose wave length is very small, then Steinhauser's theory of the *relative intensities* appears to hold good. It may possibly hold good in the case of very low tones, where the differences of phase could be (since the waves are so long) only very slight. Any one may easily convince himself, however, that it is possible for diffraction to produce a very marked difference in the relative intensities with which the partial tones of a compound sound reach the ears. For this, the simple experiment suffices of comparing the *note* of a musically-ticking clock, placed in front of the head, with its note when placed an equal distance behind. The sound will seem almost as loud, but there is a very decided difference in the *timbre* of the note.

In conclusion, it appears, in the present state of our knowledge, impossible, as yet, to decide whether difference in phase, or in intensity, or in quality, of the sounds that reach our two ears is to be regarded as the criterion by which we judge of the direction of a sound.

Remarks on the Preparation of a Local Flora.

By J. WALTER WHITE.

THE study of Geographical Botany has of late years attracted much attention, and in this country the investigation of the history and distribution of our plants, has been pursued with ardour, by men of the highest attainments in botanical science.

Their efforts have been very greatly assisted, indeed we may almost say, have been rendered possible, by the labours of local Botanists, who have recorded accumulations of small facts concerning the species inhabiting their special districts, and have examined with more or less accuracy the floral peculiarities of the soil on which they dwell. The rapidly increasing number of reliable local records extends and supplements the knowledge acquired by personal investigation, and enables the Phytogeographer to trace out the diversities and similarities of the Floras of various parts of the kingdom, helping him in his endeavour to ascertain the circumstances or influences, which have determined the existing conditions of plant distribution.

By means of these records also one can compare the botanical geography of our own country with that of any other; or one part of itself with another. The relative distribution of different species may also be studied. It is perhaps from these considerations that we may derive the truest idea of the value of Local Floras, although their utility may be demonstrated on many other grounds.

The desirability of possessing carefully worked records of local Botany being admitted, I will pass on to consider the manner in which a work of this kind should be produced, in order to possess true scientific value; throwing out a few crude thoughts upon various portions of the subject as they are reviewed.

In the first place, respecting the man who may endeavour to construct a Local Flora.

He will be of course an experienced Botanist, fairly acquainted with our critical genera, otherwise his labour in going over the same ground repeatedly will be vastly increased.

Further, it is most desirable that he should not have confined his studies to the Botany of this country, but should have a comprehensive knowledge of European plants. He will then know what to look for, and will the more readily recognize continental species: stragglers, introductions, or otherwise, which may exist in his area. For like reasons, he should be acquainted with the Flora of the country adjoining his particular district. Other desirable qualifications are, a good development of the sense of colour, and a quick and trained eye to differentiate. Granted that he is an enthusiastic worker, able to devote entire leisure to this pursuit, let him be also a man of little faith, wary and circumspect in adopting the views of others, patiently and cautiously investigating all things for himself. Lastly, by all means, let physical vigour be added to mental capacity, so shall our author be enabled to brave exposure, and withstand fatigue during his lengthy rambles.

As the first preliminary to actual work, the district to be examined must be mapped out, and a natural or arbitrary limit assigned to it.

For an inland Flora, it seems to me that an area having a radius of seven miles would afford ample scope for the exertions of any Botanist, however energetic, who works single-handed and hopes to publish his work in a state approaching completeness.

Our own case is exceptional; although, looking at the extent of country, it may be considered with some reason that in determining to work up the Flora of the Bristol Coal Fields, we have attempted a task beyond our powers. This, however, is the joint work of the members of the Botanical Section of this Society, some of whom have studied the Bristol Flora for many years. Also, our confreres, the geologists and entomologists, had already adopted the same area. For the sake of uniformity, therefore, we felt constrained to follow their lead.

I believe I speak within the mark in saying, that the Flora of an average-sized county cannot be satisfactorily compiled by one man, unless nearly his whole life be given to the labour, and even then it would be impossible for him to claim that the district had been exhaustively searched. Doubtless there are extant, well-worked county Floras; but it will usually be found that portions of the area had previously been examined, and the records used by the more ambitious Botanographer, whose work was thereby greatly facilitated. It seems right to lay stress on this point, as, without doubt, a Flora should not go forth until it has been made as complete as possible, and of course the more extended the area, the greater the difficulty in complying with this proviso.

For be it remembered, that unless every yard of land be carefully examined, and every ditch and pool peered into, there can be no comfortable sense of having thoroughly done the work. Many species will have been overlooked. In proof, take the existence of *Menyanthes trifoliata* in Leigh Wood, the single spot for many miles around Bristol, where this plant can be found. Or the equally remarkable presence of *Scutellaria minor* on the margin of another pool, where it remained unheeded and unknown to the Bristol Flora, until a few years ago; though scores of botanists must have passed yearly within a stone's throw of the place. Perhaps more singular still, was the

discovery of *Alchemilla vulgaris* in a frequented part of Leigh Wood, near the Suspension Bridge, where its presence had never been dreamt of, until Mr. Bucknall happily noticed it.

The well-known lines from Gray's Elegy are most appropriately remembered, as one dwells upon these examples, of which one more may be given. *Bidens tripartita* had not been included in the Flora of Weymouth until the other day, when a friend of mine found a ditchful of it on the Lodmoor, a marsh contiguous to the town. Now, my friend and I have botanized upon the Lodmoor perhaps a hundred times, and many others also, yet apparently, because we all followed an inviting track, this out of the way ditch was never visited. The lesson to be here learnt is, that paths and beaten tracks are to be avoided, and that it is in the most unfrequented, unattractive, and unlikely situations, that discoveries are chiefly to be made.

A maritime district being necessarily bounded by the coast-line, at some point on which its centre will be placed, approaches more or less to a semicircle in outline, and might, on account of the reduction in area, have an increased radius, say of twelve miles. This limit was adopted by Mr. Archer Briggs in his most admirable Flora of Plymouth.

If the geographical features of the country permit, it may be deemed advisable for convenience of record, that the area within the limit be divided into subordinate districts. These should be clearly defined on the map to be published with the Flora.

As a second preliminary, there arises the very important and practical question of classification and nomenclature—the arrangement and naming of the plants. On what lines shall the new Flora be constructed, in order that it may fulfil the highest requirements? Shall it reflect the views of Bentham, Babington, Boswell Syme, or those of the compiler of the London Catalogue? These very influential authorities differ

greatly, *inter alia*, upon a point of the most vital moment to works like the one now treated of. They have diverse methods of separating or grouping, of segregating or aggregating plants. Now it is unnecessary for our author to enter upon the study of natural affinities, or to entangle himself in an attempt to define what is a species, and what something else. Luckily he is relieved from all speculation on this vexed question. He will probably have views of his own, but their expression would be out of place in the pages of his work His task is a purely practical one: in the first place, that of discovering the plants which grow in a particular tract of country; and, secondly, of recording their names and habitats, in language perfectly intelligible to other botanists.

To do this latter, he must follow one of the systems of nomenclature given to us by leading botanical writers. Some of these have chosen to keep alive the old aggregate species named by Linnæus, Hudson, and Smith; whilst others, less conservative, and more discriminating, have recognized and described the large number of subordinate segregates, which those aggregates include, and which, as time moves on, become more and more clearly understood by, and familiar to, students of field botany. Perhaps the book most representative of the views of the older botanists, is Bentham's "Handbook of the British Flora." It has met with much commendation, and is doubtless an almost perfect guide to beginners in the science. In it the aggregation or "lumping" of species is carried to an extreme, which, however convenient it may be in relieving a learner from perplexity at the beginning of his study, detracts largely from the usefulness of the book, in making records of localities and other like purposes. As a matter of fact, in my own experience, I find that six out of every seven amateur botanists, put their trust in the "Handbook," and from their point of view very properly so indeed. But when these

botanists are appealed to for assistance in compiling a local Flora, of what value is the bulk of their notes and records? When our author is informed that *Ranunculus aquatilis* has been gathered in such a situation, what significance can he possibly attach to the circumstance? None whatever. He is supposed to be well acquainted with three or four distinct species, which come under this particular aggregate, and whatever he may think of the other segregates, which are frequently separated from it, he wishes to record them all, if found in his locality, by names which will tell precisely what is meant.

In this way only can the special distribution of the segregates be ascertained; and to exclude these from the Flora, would rob it of much value, if not render it entirely useless.

The requirements of science therefore will make it necessary to arrange the Flora on a broad basis, and the writer probably cannot do better than follow the London Catalogue, or Babington's "Manual"; being careful to state explicitly which edition is adopted.

The work of compilation will commence with the search for, and examination of, old records relating to the locality. Some of the more noteworthy plants will probably have attracted attention a century or two ago, when, in the early dawn of the day of science, the first field botanists went forth through the land. And these early notes, mingled though they may be with much that now proves to be erroneous and absurd, are often of great interest, and afford, in some cases, valuable evidence on the nativity of rare plants still surviving in their ancient habitats.

Towards the end of last century, Mr. Sowerby gathered *Tragopogon porrifolius* in a field by the Avon, below Cook's Folly; and the specimen is figured in Smith's "English Botany." The plant seems to have disappeared from that locality shortly after it was seen by Mr. Sowerby, and for very many years his

record was the sole ground for its inclusion in the Bristol Flora. However, after the construction of the Port and Pier Railway, when the ground at that spot was much disturbed, the *Tragopogon* again appeared, and was to be seen during several seasons, though I fear it will not be permitted a permanent residence. Undoubtedly this reappearance proves the accuracy of the old recorder, and the old record returns the compliment by affording strong evidence of the nativity of the plants recently gathered; these might, in its absence, have been considered casual introductions, deserving no place in the Local Flora.

It will be found that the geography of some old botanists was very greatly at fault. For instance, the Isle of Portland, off the coast of Dorset, has been said to belong to Cornwall; and the town of Plymouth, in Devonshire, was also allotted to the adjoining county. A minor error of the same sort, was the assumption, that our St. Vincent's Rocks were located on both sides of the Avon, and, in consequence, that both the counties of Somerset and Gloucester might lay claim to the rarities growing thereon.

Another, but less frequent, source of difficulty in this relation is, that a single station by being variously noted in different works, and by being copied by one author after another, may at last come to be considered as three or four. Anything more misleading than this multiplication of records, can hardly be conceived.

The old recorders naturally noted the aggregates, the books of past generations therefore do not give assistance in working up the critical genera.

The attempt to eliminate errors from old literature is scarcely more necessary than the cautious avoidance of those of more recent date. Records of localities in Guide Books, and other like sources of information, are to be viewed with great suspicion. Such records are unfortunately sometimes inserted

on little or no authority, and their acceptance might give permanence to many errors.

With respect to the form in which each station is to be noted in the Flora, the author will exercise his discretion as to whether the exact habitat of a plant shall be indicated or not. When the plant is rare, or grows sparingly, it will be wise to give it protection by describing rather loosely the place where it is to be found. In such a case, it seems to me that the mention of the parish, or nearest village, would be quite sufficient for the purpose. This view, however, will not find universal acceptance, for it was lately suggested, in the pages of a popular periodical, that the chief object of a Local Flora should be to point out the exact spots where the more uncommon plants of a district are to be found! It was calmly remarked, that minute descriptions of the localities, specifying even the roads and paths to be taken, "would be a very great advantage." Doubtless, but to whom? Certainly the rapacious plant collector, eager to make up his bundle for the Exchange Club, will eye with dismal scorn the "mere Catalogue with its vague remarks," which does not spread at his feet the treasures enumerated therein, and humbly entreat him to root them up. But it is not for such as this that the local botanist toils, season after season, at his difficult and pains-requiring task. A keen delight possesses the true naturalist, when he discovers a rare plant, or one not suspected to grow within his reach. Will he not guard his fortunate discovery with jealous care, instead of straightway inviting all and sundry to its extirpation; and look askance upon the "battue-shooters," who go forth with reams of paper, and coffins of japan wherein to inter every green thing, which may be a desideratum to their correspondents or themselves? The gathering and distribution of specimens by wholesale can at best bear the very smallest relation to botanical science, and if *any* public benefit be reaped thereby, it cannot

for a moment be considered compensation for the abhorrent and ruthless destruction of native rarities. It seems also that care for his own reputation should restrain the writer of a Flora from publishing exact stations for scarce plants. It has very curiously happened to a well-known botanist, that his accuracy has been impugned, because some habitats very precisely indicated in his County Flora no longer yield the plants with which they once abounded; and disappointed searchers, not recognizing the mischievous result of proceedings like unto their own, were impolite enough to say that the records were erroneous.

In field work some difficulties are to be encountered in the present day, arising from extended cultivation. The plough is rapidly altering the surface features of the country. Heaths and commons are being enclosed, bogs and marshes reclaimed and drained. The extent of aboriginal wood and virgin sod is gradually diminishing. Thus it happens here and there, that a species has become extinct, through the removal of conditions necessary for its existence; whilst many others increase in rarity, as man's interference with the soil makes their position on it less tenable. Improved systems of farming, too, tend to destroy weeds of cultivation, and help to guard against plethora in the botanist's vasculum. A friend writes, that he has this season been conscious of an undue predominance of bulls of a ferocious type in the pasture lands of his district. This certainly ranks as a practical difficulty.

But there are advantages also by which the modern field botanist can largely profit. It is no longer necessary, as in the old days, to expend a fortune in becoming master of a science. Precise information in books can be had at very moderate expenditure, or may with ease be referred to in public institutions, where also good series of specimens are frequently to be found. Optical instruments are good and cheap. Railways have grown into a network of invaluable locomotive facilities,

saving time and sparing leg-weariness. Improved postal communication permits consultation with friends, and valuable assistance in the identification of plants to be received from the best authorities. These are indeed great advantages, and, if used as they deserve to be, with energy and perseverance, will help on the naturalist to attain that great proficiency, and superior accuracy which should ever be his aim.

Darwinism.

By CHARLES JECKS.

WHAT is the meaning of the term "Darwinism"? or what are those opinions, which, in the aggregate, are called the "Darwinian Theory"? I believe these. Given the occasional variation in structure of a plant or animal, that, if this variation tend towards its welfare, but not otherwise, such plant or animal will thus be given certain advantages over others less favoured, which advantages will, by the law of heredity, tend to increase, and in this way, supposing that any form of life give rise to a variety in the structure of its progeny, advantageous to its existence, and sufficiently marked (its surroundings, as regards other organisms, being favourable), the form of life in which this variation appears, being thus able to survive in circumstances injurious or fatal to other forms, hands down to its progeny these advantages in an ever increasing ratio, the ultimate results being what we call a species.

It will thus be seen that there can be no direct connection between the parent-form and its remote descendant, for these are separated by many other forms, each of which is noted for a more or less marked variation from the original stock, one form sometimes diverging into two or more branches, as represented in the diagram in Mr. Darwin's "Origin of Species," so that the original form would be almost lost. We cannot, therefore, thus reasonably expect to find any two forms of life connected together by any unbroken line of descent, but must, on the other hand,

be prepared to meet with several apparently broken links. Indeed, there would naturally be such an amazing amount of modification between the parent-form and its remote descendant, and this would be expressed in so many and such divergent ways, that the apparent absence of any connecting links, so far from being an objection, is a necessary result of the theory, and really rather an argument in its favour than otherwise, because it is just what we might reasonably have expected. This, then, so far as I understand it, is the meaning of the "Darwinian Theory," which, I need scarcely say, has been more misunderstood, and, as a natural consequence, more misrepresented, than any other of our day, but which is, after all, generally and increasingly acknowledged to be the best if not the only workable theory extant. As regards the opposite one—that of Special Creation—I think that any one who has read attentively and thoughtfully the works of Messrs. Darwin and Wallace—especially the curious and interesting facts related by the former in his chapter on "Geographical Distribution" ("Origin of Species")—will surely be convinced that, judging from all that we know upon the subject, it has no reasonable basis. The Development Theory, as it is called, has also the advantage of being capable of legitimate application to vegetable and animal life in a wider sense than any other. It would seem, indeed, as if by it we had touched the very warp and woof of organic life, and were, at length, in a fair way to get some faint glimpses of the great central ruling principle, intertwined as it is in the labyrinth of being, and branching out in many different ways.

As one instance of this capacity for broad application, I think that of what are called "Insectivorous Plants" presents itself. It is well known that these have generally but slight and insignificant roots, depending, as they do, chiefly upon insects for subsistence, though in a different and perhaps more literal way to that which we have been used to observe in the

fertilization of plants. Now, as regards the origin of these curious forms of life, let us suppose that a plant be placed in certain abnormal conditions, so as not to be able to derive nutriment from the usual source—the roots; is it not possible that the organs of absorption would be increased in power in the effort to adapt the plant to the circumstances in which it is placed, and to supply the needed nutriment in another way? till at length by reason of a favourable variation, sufficiently marked to be taken hold of by natural selection, and increased by the law of heredity, these organs are not only increased in power, but perhaps altered in function, and united with appropriate glands, the whole structure being correlated as to the possession of hairy appendages, &c., suitable to the requirements of the plant. With regard to the retention of insects, we know that the leaves of many plants exude a gummy matter, which serves to attach them (insects) to the surface of the leaf, and have only to suppose it to be an advantage to the plant to have this exudation increased, with the object of supplying a source of nutriment; this being probably effected, first, by the decomposition of the animal matter and its absorption as a kind of manure, when the plant may be said to be partly insectivorous—in a transition state; and then, the appearance through a favourable variation, of the direct digestive power, which, giving the plant a more decided advantage over others, would, if sufficiently marked, be laid hold of by natural selection and the law of heredity, and at length become confirmed. We know at present little or nothing regarding these curious forms of life; but it may perhaps be suggested as probable that they differ much as to the power of digesting insects; and if this be so, the plant which has most power of this kind will have an advantage over others, and will therefore tend to increase.

If, however, the plant be thus benefited, it seems but reasonable to believe that though the individual insect derives no

advantage, the species may do so, for it is quite possible (and all analogy tends to strengthen the idea) that the rationale of the insect falling a prey to the plant, is the possession by it of some organic imperfection not found in others.

That which we call beauty in plants and animals, and protective resemblance, seems also to come under the action of development by natural selection. What do we mean by the expression "Utility of Beauty"? and is the possession of beauty or adornment of any service to the form of life in which it is found as a means of giving it any advantage over other forms? The answer which Mr. Darwin and others, including, I believe, Messrs. Wallace and Bates, would give to these questions is—That beauty in all its forms seems to be of real and essential service, and that its possession does really give a certain tangible advantage over other forms of life. Thus, according to the views of Mr. Darwin and others, the possession of what we call beauty, in plant or animal, is not so much an end in itself as a means towards an end, which, in so far as the plant or animal is concerned, is higher and more important than mere beauty, because it contributes towards its welfare and preservation in the great battle of life, and this is surely of more real importance than that the sole or even the chief end of beauty should be to call forth the idea in ourselves. We also find that both beauty and protective resemblance exist in places and under circumstances in which they are hidden from human eyes, and it would seem from this that they are rather a natural result of a variation in colour, &c., which tends towards the advantage of the form of life possessing it, than expressly developed to please our sense of beauty. Moreover, though it frequently happens, it is not always the case, that these variations in colour or resemblance to other forms of life are in themselves what we should call beautiful, though they may be of equal advantage, for in those cases which strike us most prominently it may perhaps be

suggested that it is often because we are naturally more impressed by what is beautiful or pleasing to the eye, and so more readily bear it in mind. The instances in which the possession of beauty or of a resemblance to another form of life are known to be of advantage to animals and plants are too numerous to need mention. Many of both kinds will, I doubt not, occur to you. In that, however, of plants we cannot help noting that while many parts of a plant are remarkable for their beauty, still the idea of beauty as an end seems to be kept in subordination to that of utility. Now, what can be more natural or appropriate than the application of the "Development Theory" as a means of explaining these phenomena? We know that variety in colour and adornment are often advantageous to the plant or animal possessing them, and have, therefore, only to suppose that these originally arose from a slight variation which, being advantageous, was seized upon by natural selection and increased by the law of heredity, till at length the desired end was effected. We have thus, I think, a far higher and more satisfactory reason for the existence of beauty in so many and such varied forms, and also a more rational explanation of that singular phenomenon—protective resemblance—than any other theory can give us.

Mr. Darwin's theory has also thrown an altogether new light upon the succession of life upon the globe, for instead of a certain form of life always making its appearance exactly at a given period, when everything seems to be prepared for it (if I may be allowed the comparison) like the transformation scene of a pantomime, we find that fitting conditions seem to have occurred without the presence of this form, whence, together with the fact of the lower forms of life generally preceding the higher in a gradually ascending scale, we are led to the conclusion that in all probability the continued succession of life on our globe is governed more by the immediate precession of lower forms than by suitability of outward surroundings. A

great difficulty connected with the Development Theory is its application to those forms of life in which development seems to be of no service—at least for the course of several generations—until it is perfected, as, for instance, in the case of the electrical eel. Here, however, the law of correlation of structure may perhaps help us, for if, as I am inclined to believe, all variations are attended by a correlation of structure, then a variation in a given direction and possibly commencing from within, and attended by a corresponding correlation—both being advantageous to the fish—at length finds expression in what we call development in the formation of the electric organ.

As to the future of Mr. Darwin's theory, I am, I confess, very hopeful, and cannot help believing that it will ultimately cover a much wider field than now, embracing man himself, with all his moral and intellectual faculties, as well as his mere physical form. Towards this, I think, all our scientific progress leads the way; every newly-discovered fact in biology brings us nearer to the advent of a general recognition of the imminent presence throughout all life of a gradual evolution from lowest to highest, finding its expression in a thousand varied ways, yet manifesting through all the great key-note of unity in diversity.

Why, of any two forms of life, both exposed to the same outward conditions, and both, perhaps, belonging to what we call the same species, should the one flourish and the other gradually become extinct? All that we can say is that we do not know. But if we do not know the causes of extinction, if we cannot tell what those mysterious influences are, by reason of which a plant or animal becomes more and more rare, and finally disappears altogether, we surely have no right to be surprised at its extinction; for, as Mr. Darwin has well remarked, "This is as if one should not be at all surprised at a man's falling ill, or at his getting gradually worse, but should be amazed beyond measure at his ceasing to exist."

We all know that however startling the effect may be, the causes of extinction are continually going on around us, and are common to all forms and all conditions of life; and we know, too, that while some forms become extinct, others flourish. These things are more and more impressed upon our minds every day, and though we cannot tell all the causes of the phenomena, it may surely be affirmed that the "Origin of Species by Natural Selection" is, if not the principal, at least one of considerable weight and importance.

A New Phonautograph.

By Professor SILVANUS P. THOMPSON, D.Sc., B.A.

THE Phonautograph, invented in 1859 by Léon Scott de Martinville, of Paris, and perfected by Dr. Rudolph König, is an instrument for recording graphically traces corresponding to the vibrations of sounds. It consisted, in the original (and usual) form of instrument, of three essential parts:

(*a*) A receiver, in the shape of a hollow paraboloid closed at the lower end by a thin membrane of skin to take up the vibrations.

(*b*) A light style made of a hog's bristle attached to the membrane, and working with guiding levers or joints.

(*c*) A recording apparatus consisting of a cylinder covered with smoked paper to receive the traces of the style, and rotating upon a screw axis which at the same time carried it longitudinally forward.

With this instrument Scott and König made a number of researches about the years 1859-64, and examined the traces of a good many sounds.

Simple musical tones gave simple harmonic curves as their traces.

Simple combinations of consonant tones gave more complex harmonic curves.

Mere noises produced totally irregular traces.

The vowel sounds gave complex harmonic curves, thus affording confirmation of their structure from certain partial tones.

Consonants were scarcely recorded at all.

This instrument had a more grave defect. The membrane of skin stretched over a brass ring possessed a tone of its own, and vibrated more strongly in resonance with this note than with others.

Since the invention of the Phonautograph several other acoustical instruments of the highest importance have been invented.

(1) *Barlow's Logograph,* described before the Royal Society, in 1874, is an instrument for measuring the varying pressures of air in the cavity between the lips during speech. It consists of a trumpet-shaped mouthpiece, fitting almost tightly to the lips, which narrows, then widens, and is closed by a piece of elastic indiarubber, which bulges out more or less according to the pressure exerted by the air upon it. Against this elastic membrane rests a light lever of aluminium, hinged at one end to the supports of the instrument, the longer end of which carries a small pointed camel's hair brush, which is charged with ink, and the lip of which touches a strip of paper carried beneath it by clockwork, like the paper strip of the Morse telegraph instrument.

The traces obtained by the Logograph do not correspond, strictly speaking, to sounds at all, and do not represent sonorous vibrations; they give the mechanical displacements of the air due to the change of wind-pressure in the cavities of the mouth during articulation. Vowels and musical sounds made no trace at all in the Logograph.

(2) The Speaking Telephone of Graham Bell, invented in 1876, first proved that metallic plates can accurately take up and reproduce the vibrations both of consonants and of vowels.

(3) The Phonograph of Edison carried this discovery one

stage further; for in this instrument the metallic disc not only took up the vibrations both of vowels and of consonants, but recorded them by indenting their form into tinfoil, and reproduced them again when forced mechanically to follow the ups and downs of the recorded tracing.

Our knowledge of the exact nature of the *vowel*-sounds, and of the characteristic form of their vibrations, is now very complete, thanks to the independent researches of Helmholtz, Donders, and König, and to the study of their traces with the Phonautograph and Phonograph.

Our knowledge, on the other hand, of the exact nature of the vibrations of the consonants is extremely imperfect. The Phonautograph did not record consonantal tracings; the Logograph merely recorded mechanical displacements due to varying air pressures.

I therefore have proposod a new Phonautograph for the purpose of investigating the quality of the consonantal sounds. Its receiver is precisely like the receiver of my Phonograph—a disc of ferrotype iron, behind a mouthpiece like that of the Telephone. A small system of levers, working on spring joints, carries the motions of the disc to a needle-point which rests lightly above a horizontal bed, along which smoked pieces of ordinary window-glass are drawn by a clockwork arrangement.

I believe it will be of great advantage thus to substitute tracings on a flat surface for tracings on a cylindrical one, as they can more easily be taken away from the instrument for purposes of observation, and for observation in the microscope. I also invite attention to the clockwork arrangement, and the means by which a perfect maintaining motion is obtained with a weight hanging upon an endless chain which passes over a winding pulley armed with a ratchet-click, as well as over the driving pulley.

No connected experiments have yet been made with the

instrument, which will probably require some further modifications. I hope at a future day to have the honour of laying before the Society, or before its Physical and Chemical Section, an account of the investigations which I purpose to make with the new instrument.

The Boulders of the Bromsgrove District.

By OLIVER GILES.

THERE are in and around the town of Bromsgrove a large number of erratic blocks, or boulders. Having spent the earlier years of my life in their immediate vicinity, I became familiar with these remarkable stones. At that time, however, I regarded them simply as *stones*, and nothing more; much as Peter Bell looked upon the primroses on the river's brim; but, with a little geological knowledge these blocks assumed quite a different aspect. My curiosity was aroused; I looked around to see if I could find the rocks, from which they came, but could find nothing approaching to them in structure, or appearance. The local rocks being of Triasic age, and composed of Bunter Sandstone, Bunter Conglomerate, and Keuper Marls, I became anxious to know whence they had come, how they had travelled, and how they had been deposited in their present position. Upon asking some of the older inhabitants, I was told that in days gone by, when there were giants in the land, they were in the habit of quarrelling, and throwing stones at each other; and that they used stones as weapons of warfare, pitched battles being sometimes fought by different tribes, one party being stationed on Malvern Hill, and another on the Lickey; the Malvern party having flung these stones at their enemies on the Lickey, a distance of about twenty miles in direct line. Most of these blocks lie round about the foot of the Lickey Hill. This legend is still believed by many of the old people in the locality, while others will tell you, that

"them stooans wun left were they bin now by the flud," meaning by the flood, the Noahic Deluge.

But, apart from legend, these travelled blocks have assumed an important position in geological science during the last few years; so much so, that a committee was appointed by the British Association to examine, map, and, as far as possible, adopt means to preserve, for the study of scientific men, these remnants of the great ice age, for such they are proved to be. Large numbers of these stones have been utilized in various ways; some in foundations of houses, walls, &c., others as parish boundaries and the like, while several are used as curb-stones and as seats for wayfarers, &c. Besides those which the British Association Committee examined, and described, I have discovered several, since their visit to the locality, many of which are partly buried.

The whole, or nearly so, of these remarkable boulders have been traced to the Arenig Mountains in North Wales, and were doubtless dropped from floating ice. As the ice floes travelled southward, they would become melted by the warmer atmosphere, and these, with other rock *débris* of much smaller dimensions, such as sand and gravel, which is sometimes called "Northern Drift," would be dropped upon the then sea bottom. And as the land rose again, and the ocean bed became dry land, such blocks became exposed to view. It is a little remarkable that so many of these boulders should remain *in situ* during the many ages that the land has been under cultivation. Some, we know, have been removed from their original positions; one at the Woodrow, a few years ago, having been a hindrance to the cultivation of a certain field, the farmer hitched the whole of his horse power to it, and removed it from the field to an adjacent lane, where it now remains. This is one of the largest in the district. I do not know of more than one block, which shows ice markings: it is a large block, and lies in a lane near Finstal Park. They are all,

more or less, sub-angular; some of the more compact blocks having suffered less by atmospheric erosion than the softer ones. There are three varieties of felspathic rock among them; one with small porphyritic crystals, one very compact, and one a decided ash. They vary in colour, from light grey to dark grey —frequently with a bluish tinge. The following is a list of the principal boulders in this locality:—

	Dimensions.	Height above the sea in ft.
Corner of road near Station, compact felstone (C. F. below) ...	2′ 0″ × 2′ 0″ × 3′ 0″ ...	275
Close to Railway Bridge, three fragments felstone with quartz.		
Near Finstal House, three boulders with fragments, C. F.	2′ 0″ × 2′ 0″ × 2′ 0″ ...	276
Another, 100 yards up East Road, felspathic ash (F. A. below) ...	5′ 0″ × 3′ 6″ × 3′ 0″ ...	280
With four smaller, near Webb's Farm.		
Near Stoke Elm and Canal Bridge, almost hornstone	2′ 0″ × 1′ 6″ × 1′ 0″	
Near Meadow Farm, felstone.		
On Hanbury Road, near Stoke, greenish F. A....	21″ × 14″ × 12″	
Opposite Stoke Church, with smaller ones, F. A.	18″ × 15″ × 12″	
At Fringe Green, horny F. A. ...	5′ 6″ × 4′ 0″ × 2′ 4″ ...	273
Several on new road to Bromsgrove, felstone...	...	270
Near Police Station, several ...	...	292
Others, similar in structure, corner of Old Station Street, Hobbis's Yard, Chapel Street, Mill Lane, Alcester Road, &c., at heights varying from		282 to 296

	Dimensions.	Height above the sea in ft.
Dog Lane, Cat's Hill, felspar porphyrite (F. P. below)	4′ 8″ × 2′ 6″ × 1′ 9″ ...	410
Near Canister, with another almost as large, F. A....	3′ 0″ × 2′ 0″ × 1′ 8″ ...	415
Near Woodrow, at corner of road to Lydyate Ash, F. P.	6′ 9″ × 2′ 9″ × 1′ 6″ ...	858
Near Whetty, angular, F. P. ...	8′ 5″ × 4′ 0″ × 2′ 0″ ...	700
At Burcott, F. A.	3′ 0″ × 2′ 0″ × 1′ 6″ ...	380
Corner of Perry Hall, opposite church, dolorite	2′ 0″ × 1′ 6″ × 1′ 0″ ...	280
Near Halfway House, F. A. with quartz	4′ 0″ × 2′ 0″ × 1′ 3″	
Ditto, with several others near, F. A. with quartz	3′ 0″ × 1′ 0″ × 1′ 3″	
At Woodcote Farm, with eight others near, F. A.	4′ 0″ × 2′ 0″ × 4′ 0″	
In addition to the above, two large groups are reported at King's Norton, some of which have been worked into the foundation of the church tower.[1]		

[1] I am indebted to the British Association Reports for the lithological character and measurements of the boulders.

Catalogue of the Lepidoptera of the Bristol District.

PART IV.

BY ALFRED E. HUDD, M.E.S.

DELTOIDES.

HYPENA PROBOSCIDALIS. L. Abundant everywhere.

„ ROSTRALIS. L. GLOS. Scarce at Almondsbury, Woodchester, and Wotton-under-Edge.
SOMERSET. Wells and Weston-super-Mare.

HYPENODES ALBISTRIGALIS. H. GLOS. Frome Glen, Durdham Down, and Wotton-under-Edge.
SOMERSET. Leigh Woods, Portishead, &c. Sometimes common at sugar.

„ COSTÆSTRIGALIS. S. GLOS. "Bristol:" *Stainton's Manual,* Vol. II.
SOMERSET. Woods at Leigh and Portishead.

RIVULA SERICEALIS. S. GLOS. Durdham Down, Almondsbury, Wotton-under-Edge, &c.
SOMERSET. Leigh Woods, Portishead, Weston-super-Mare. Not very common.

HERMINIA BARBALIS. L. SOMERSET. The only record in the district is by Mr. Crotch, from Weston-super-Mare.

„ TARSIPENNALIS. T. GLOS. Durdham Down, Ashley Hill, Almondsbury, Wotton-under-Edge, &c.
SOMERSET. Leigh, Brislington, Portishead.

HERMINIA GRISEALIS. W.V. Abundant everywhere.

„ CRIBRALIS. H. SOMERSET. Several specimens were taken some years ago on the moors near Glastonbury, by Dr. Livett, of Wells.

AVENTIÆ.

AVENTIA FLEXULA. F. GLOS. Woods near Cook's Folly, Almondsbury, and Wotton-under-Edge. Scarce.

SOMERSET. A few specimens only have been recorded; from Portishead, by Mr. I. W. Clarke; from Nailsea, by Mr. Collison; from Weston-super-Mare, by Mr. W. H. Grigg; and from near Bath, by Mr. Ross.

PYRALIDES.

PYRALIS FIMBRIALIS. L. GLOS. Mr. Perkins reports several specimens from Wotton-under-Edge.

„ FARINALIS. L. Common everywhere, in stables and granaries.

„ GLAUCINALIS. L. GLOS. A few specimens have been taken at Stapleton, by Mr. Harding and Mr. H. Bolt, and one at Clifton by myself.

SOMERSET. A few at Brislington, by Mr. Ficklin.

AGLOSSA PINGUINALIS. Common everywhere, in farmyards and out-houses.

„ [CUPREALIS. H. GLOS. I took a specimen at Stapleton, in the summer of 1869, which I believed to be this species; but as it was in very poor condition, I do not feel sufficiently sure of its identity to include this local species in my list.]

[CLEODEOBIA ANGUSTALIS. L. SOMERSET. This species is not uncommon on the hills near Minehead, but I have no records from my district.]

PYRAUSTA PUNICEALIS. W.V. GLOS. Durdham Down, Wotton-under-Edge.

SOMERSET. Leigh Woods, Brockley Coombe, Portishead, Weston-super-Mare, &c.

„ PURPURALIS. L. GLOS. Durdham Down, Wotton-under-Edge.

SOMERSET. Brockley Coombe and Weston-super-Mare. This species is much less common in this neighbourhood than *P. ostrinalis*, from which, I believe, it is distinct. They are, I think, seldom found flying together.

„ OSTRINALIS. H. Common everywhere, on heaths and downs.

HERBULA CESPITALIS. W.V. On heaths and downs; not so common as the last-named species.

ENNYCHIA CINGULALIS. L. GLOS. Durdham Down.

SOMERSET. Leigh Down, Portishead, Clevedon, &c. Not common.

„ ANGUINALIS. H. GLOS. Durdham Down, Worcombe, Almondsbury, Wotton-under-Edge.

SOMERSET. Leigh Woods, Clevedon, Weston-super-Mare.

ENDOTRICHA FLAMMEALIS. W.V. GLOS. I used to take this commonly on Clifton Down.

SOMERSET. Brislington, by Mr. Vaughan.

DIASEMIA LITERALIS. S. GLOS. Mr. Harding took two specimens of this very local species on a gas lamp at Baptist's Mills, near Bristol, some years ago. It has also been met with in the Dean Forest District. See *Intelligencer*, Vol. III.

STENIA PUNCTALIS. W.V. SOMERSET. Reported from Weston-super-Mare, by the late Mr. G. R. Crotch.

CATACLYSTA LEMNALIS. L. Abundant everywhere, over duck-ponds and stagnant pools.

PARAPONYX STRATIOTALIS. L. GLOS. Among reeds on the banks of the river Frome, at Stapleton, and at Wotton-under-Edge; not common.

SOMERSET. Near Weston-super-Mare.

HYDROCAMPA NYMPHÆALIS. L. Tolerably common on the banks of streams and rivers throughout the district.

„ STAGNALIS. D. In most of the localities of the last named, and more abundant.

BOTYS PANDALIS. H. GLOS. "Woodland Copse," near Almondsbury, by Mr. Hill; Dursley, *Stainton's Manual;* Wotton-under-Edge, by Mr. Perkins.

SOMERSET. Weston-super-Mare. Scarce.

„ HYALINALIS. H. GLOS. Scarce, among nettles, &c., on Durdham Down, and near Wotton-under-Edge.

SOMERSET. Leigh Woods. Scarcer than formerly.

„ VERTICALIS. W.V. Abundant everywhere among nettles.

„ LANCEALIS. W.V. GLOS. Dursley, *Stainton's Manual,* Vol. II.; Wotton-under-Edge.

SOMERSET. My brother and I met with several specimens near Rownham Ferry some years ago, but I have heard of no recent captures.

„ FUSCALIS. W.V. GLOS. "Hedges and wood-sides near Almondsbury; not common." J. A. Hill; Wotton-under-Edge.

SOMERSET. "Rare in Portishead Wood." J. N. Duck; Brislington, P. H. Vaughan; Weston-super-Mare, by Mr. Crotch. *Stainton's Manual* says of this species, "Common everywhere"; but, like other species so described in that work, I have never seen a live specimen.

BOTYS ASINALIS. H. Common throughout the district wherever the food-plant of the larvæ—*Rubia peregrina*—grows. The presence of these larvæ can

always be detected by the white blotches they make on the madder leaves.

BOTYS URTICALIS. L. Abundant everywhere among nettles.

EBULEA CROCEALIS. H. Common in marshy places throughout the district, amongst *Inula dysenterica*, on which the larvæ may be found in April.

„ SAMBUCALIS. W.V. Throughout the district, among elders, but not very common.

„ VERBASCALIS. GLOS. Wotton-under-Edge. V.R.P. The only record in the district.

PIONIA FORFICALIS. L. Abundant everywhere in kitchen-gardens.

„ [MARGARITALIS. W.V. GLOS. Three specimens from Redland were recorded by Mr. Vaughan in the *Zoologist*, but on further examination proved to be *S. cinctalis*.—See *Zoologist*, 1974.]

SPILODES STICTICALIS. L. GLOS. A few specimens have been taken on Durdham Down by Mr. Harding; and Mr. Hill writes:—"Rare on a dry, grassy bank in Hortham Wood, in August."

„ CINCTALIS. T. GLOS. Almondsbury, Redland, Stapleton, and Wotton-under-Edge.

SOMERSET. Leigh Woods, Portishead, Weston-super-Mare. Scarce.

SCOPULA LUTEALIS. H. GLOS. Clifton and Durdham Downs, Wotton-under-Edge, &c.

SOMERSET. Leigh Woods, Clevedon, Weston-super-Mare. Not common.

„ OLIVALIS. W.V. Common everywhere.

„ PRUNALIS. W.V. Abundant everywhere.

„ FERRUGALIS. H. Throughout the district, sometimes abundant in oak-woods.

STENOPTERYX HYBRIDALIS. H. Throughout the district; common on rough ground and dry hill sides.

SCOPARIA AMBIGUALIS. T. Throughout the district, abundant.

„ BASISTRIGALIS. K. GLOS. Sidcup, by Mr. H. Jenner Fust; see *Entomologists' Annual* for 1867, p. 157.

SOMERSET. One specimen at Portbury, by Mr. Harding. One in Leigh Woods, by myself, in 1880.

„ ZELLERI. W. Marshy places throughout the district; local, and not common.

„ CEMBRÆ. H. Generally distributed, and common.

„ DUBITALIS. H. Throughout the district, abundant everywhere.

„ LINEOLA. C. "Bristol," *Stainton's Manual.*

„ MERCURELLA. L. Common throughout the district.

„ CRATÆGELLA. H. GLOS. "Bristol"; Stapleton.

SOMERSET. Brockley, Weston super-Mare.

„ RESINALIS. H. GLOS. "Bristol"; Almondsbury, "on trunks of trees in the orchard, common, but very local." J. A. Hill.

„ TRUNCICOLELLA. S. GLOS. "Common at Bristol," *Stainton's Manual.* Wotton-under-Edge.

„ COARCTALIS. Z. (=ANGUSTEA. C.) Throughout the district, on old walls, &c., but not common.

„ PALLIDA. S. GLOS. Abundant on marshy grounds near Ashley Hill and Stapleton, but very local.

SOMERSET. Bank of the Avon, opposite the Sea-Walls, Durdham Down.

CRAMBITES.

CRAMBUS FALSELLUS. W.V. GLOS. One specimen near Stapleton, by Mr. Harding.

„ PRATELLUS. C. Abundant everywhere.

CRAMBUS DUMETELLUS. H. GLOS. Common on the banks of the Avon near Sea Mills. G.H. Wotton-under-Edge.

" PASCUELLUS. L. Abundant everywhere, on marshy ground and by streams.

" ULIGINOSELLUS. Z. GLOS. Recorded from "the Boiling Wells," near Bristol, by Mr. Harding.

" PINETELLUS. L. Throughout the district, on heaths and downs; not scarce.

" PERLELLUS. S. Common on marsh-lands throughout the district.

" WARRINGTONELLUS. Z. (? *var. præc.*) GLOS. With the preceding species at Boiling Wells; not scarce. I think this is not specifically distinct from *perlellus, Scop.*

" SELASELLUS. H. GLOS. A few specimens have been taken on the bank of the Avon, under Cook's Folly, and near Wotton-under-Edge.

" TRISTELLUS. W.V. Abundant throughout the district, and variable in colour and markings.

" INQUINATELLUS. W.V. Generally distributed and common.

" CONTAMINELLUS. H. GLOS. "Bristol," *Stainton's Manual.* I have never met with more than one specimen in the district, which I took near Sea Mills, many years since.

" GENICULELLUS. H. Common and generally distributed throughout the district.

" CULMELLUS. L. Abundant everywhere.

" CHRYSONUCHELLUS. S. GLOS. Gully, Durdham Down; Henbury, &c.

SOMERSET. Leigh Down, Portishead, Clevedon, &c. Probably common amongst *Helianthemum* throughout the district.

CRAMBUS HORTUELLUS. H. Abundant everywhere.

SCHŒNOBIUS FORFICELLUS. T. GLOS. Redland, Stapleton.
SOMERSET. Brockley, Nailsea, &c. Not common.

MYELOPHILA CRIBRELLA. H. GLOS. Durdham Down, Stapleton, Ashley Hill, New Passage, &c.
SOMERSET. Cadbury Hill, Yatton, &c. Larvæ sometimes abundant in thistle-stems.

HOMŒOSOMA [NIMBELLA. Z. GLOS. "Bristol," *Stainton's Manual*. This is probably a mistake.]

,, SENECIONIS. V. GLOS. Not scarce among *Compositæ* on Durdham Down, and at Stapleton.

,, SAXICOLA. V. GLOS. I have taken a few specimens on the railway bank near the Black-rock Quarry, Durdham Down, which have been compared with specimens received from Mr. Barrett.

,, NEBULELLA. W.V. GLOS. "Bristol," *Stainton's Manual.*

,, BINÆVELLA. H. (=ELUVIELLA. G.) GLOS. "Bristol," *Stainton's Manual.*

EPHESTIA ELUTELLA. H. Generally distributed throughout the district, but not very common.

,, SEMIRUFA. H. GLOS. Taken at Redland by Mr. P. H. Vaughan ; "Bristol," *Stainton's Manual.*

,, PINGUIS. H. On ash trees throughout the district, but not common.

,, CINEROSELLA. Z. GLOS. Mr. Harding used to take this local species at Stapleton, but has not met with it lately.

CRYPTOBLABES BISTRIGELLA. H. GLOS. "Bristol." (?)
SOMERSET. Very rare. Leigh Woods, by Mr. Vaughan ; and Portbury, by Mr. Harding.

PLODIA INTERPUNCTELLA. H. GLOS. One specimen taken flying in my garden at Clifton, in 1875.

NEPHOPTERYX ANGUSTELLA. H. GLOS. Redland. P.H.V. Scarce.

PHYCIS BETULELLA. G. GLOS. Durdham Down.
SOMERSET. Sometimes abundant amongst birch-trees at Leigh.

„ SUBORNATELLA. Z. GLOS. Durdham Down, Henbury, Westbury, Almondsbury, &c.
SOMERSET. Leigh Down. Not common.

„ ABIETELLA. W.V. SOMERSET. Scarce at Brockley Coombe, among spruce-firs.

„ ROBORELLA. W.V. Throughout the district, the larvæ being sometimes common on oaks.

PEMPELIA PALUMBELLA. W.V. Throughout the district on heaths and downs.

RHODOPHÆA CONSOCIELLA. H. GLOS. Gully, Durdham Down, Almondsbury, Stapleton, and Wotton-under-Edge.
SOMERSET. Leigh Woods. Not common.

„ ADVENELLA. Z. GLOS. Durdham Down and Purdown.

„ MARMORELLA. H. GLOS. Gully, Durdham Down.

„ SUAVELLA. Z. GLOS. Durdham Down; not common.

„ TUMIDELLA. Z. GLOS. Durdham Down.
SOMERSET. Leigh and Portishead Woods.

ONCOCERA AHENELLA. W.V. GLOS. Durdham Down and Almondsbury; local and not common.
SOMERSET. Leigh Down. Scarce.

MELIA SOCIELLA. L. Generally distributed throughout the district, but not very common.

MELIPHORA ALVEARIELLA. G. Common amongst beehives.

The Fungi of the Bristol District.

PART IV.

BY CEDRIC BUCKNALL, Mus. Bac.

AMANITA.

690. Agaricus ovoideus, *Bull.*, t. 364. — Abbots' Leigh, — Oct. 1880.

New to Britain. This fine species occurred on bare ground under trees in a field near Sandy Lane. One young specimen only was found, the top of the pileus just appearing above the surface of the earth. It agrees well with Bulliard's figure, except that fragments of the volva remained attached to the pileus, forming large, flat, white warts. Unexpanded pileus 3½ inches across; stem 5½ inches high, 2 inches thick.

691. Agaricus pantherinus, *Fr.* — Leigh Wood, Shirehampton Park — Oct. 1880.

692. „ asper, *Fr.* — Leigh Wood, — Aug. „

LEPIOTA.

693. Agaricus procerus, *Scop.* — Leigh Wood, — Sept. „

694. „ granulosus, *var.* rufescens, *B. & Br.*, Ann. Nat. Hist., No. 1834. — Leigh Wood, — Sept. „

A curious form, quite pure white at first, then partially turning red, and in drying acquiring everywhere a rufous tint. *B. & Br.* (Plate II., fig. 1.)

695. Agaricus seminudus, *Lasch.* — Leigh Wood, — Sept. 1880.

696. „ Bucknalli, *B. & Br.* Ann. Nat. Hist., No. 1836 — Leigh Wood, — Sept. „

Olidus, pileo e campanulato convexo, albo, stipiteque deorsum pulvere lilacino conspersis, lamellis albis marginem vix attingentibus.

Pileus nearly 1 inch across; stem 8 inches high, dilated at the base. A doubt has been suggested whether this may not be Quelet's var. *lilacinus* of *Ag. seminudus*; but as he does not mention the strong gas-tar smell, they cannot be the same. The spores in this species are much longer, ·00027×·0001 in.; in *Ag. seminudus*, ·00015×·00007 in. *B. & Br.* (Plate I., fig. 2.)

TRICHOLOMA.

*	Agaricus terreus, v. argyraceus, *Bull.*	Leigh Wood,	Nov. 1877.

The plant referred to *Ag. scalpturatus*, at p. 208, Vol. II., is pronounced by the Rev. M. J. Berkeley to be this species. The pileus and gills become stained with lemon-yellow as the plant decays.

CLITOCYBE.

697.	Agaricus candicans, *Fr.*	Wick,	Sept. 1880.

PLEUROTUS.

698.	Agaricus subpalmatus, *Fr.*	Portishead,	July, 1880.

COLLYBIA.

699.	Agaricus platyphyllus, *Fr.*	Blaize Castle Wood,	Oct. 1880.
700.	„ butyraceus, *Bull.*	Abbots' Leigh,	„ „
701.	„ rancidus, *Fr.*	Leigh Wood,	„ „
702.	„ atratus, *Fr.*	„	„ „

MYCENA.

703.	Agaricus rugosus, *Fr.*	Westridge Wood, Wotton-under-Edge	Sept. 1880.
704.	„ sudorus, *Fr.*	Stapleton Park,	„ „
*	„ electicus, n. sp.	Leigh Wood, Abbots' Leigh,	Oct. 1879. Mar. 1881.

On dead furze, bracken, &c. Entirely white. Pileus hemispherical, at length sulcate, clothed, as well as the stem and gills, with sparkling, glandular pubescence; stem filiform, slightly dilated and hairy at the base; gills adnate, broad—four to nine.

This is No. 518, Part 3, Vol. III., where it was referred doubtfully to *Ag. sacchariferus, B. & Br.* The Rev. M. J. Berkeley, however, decides that it is new, and suggests the above name. (Plate II., fig. 2.)

VOLVARIA.

705. Agaricus Taylori, *B.* Brockley Coombe, July, 1880.

ENTOLOMA.

706. Agaricus prunuloides, *Fr.* Abbots' Leigh, Oct. 1880.
707. „ Bloxami, *B. & Br.* „ „ „

CLITOPILUS.

708. Agaricus cancrinus, *Fr.* Weston-in-Gordano, July, „

LEPTONIA.

709. Agaricus solstitialis, *Fr.* Weston-in-Gordano, July, „
710. „ asprellus, *Fr.* Leigh Down, Aug. „

PHOLIOTA.

711. Agaricus pudicus, *Bull.* { Sandford, July, „ / Portbury, „ „ }
712. „ muricatus, *var.* gracilis. Shirehampton Park, Oct. „

Quelet, Champignons du Jura et des Vosges, p. 231. Champ. Normandie, &c., (Rouen, 1880,) t. 1, fig. 3. (Plate III., fig. 1.)

713. Agaricus marginatus, *Batsch.* Haw Wood, Oct. 1879.

HEBELOMA.

714. Agaricus mesophæus, *Pers.* Leigh Road, Sept. 1880.

FLAMMULA.

715. Agaricus carbonarius, *Fr.* Leigh Wood, Oct. „

NAUCORIA.

716. Agaricus melinoides, *Fr.* Clifton Down, May, 1879.

GALERA.

717. Agaricus vestitus, *Fr.* *Quel. t. 23, fig. 3.* Stoke, Oct. 1880.

New to Britain. (Plate III., fig. 2.)

763.	Lamproderma physarioides, *A. & S.*	Clifton,	June, 1880.
764.	Trichia varia, *var.* nigripes	Westridge Wood,	Oct. „
765.	„ chrysosperma, *Bull.*	Leigh Wood,	Sept. „
766.	Cyathus striatus, *Hoffm.*	Glen Frome,	Dec. „
767.	Sphærobolus stellatus, *Tode.*	Stapleton Park,	Oct. „
768.	Sphæronema vitreum, *Corda.*	Leigh Wood,	Sept. „
769.	Diplodia fibricola, *Berk.*	The Gully,	April, 1878.
770.	Dinemasporium graminum, *var.* herbarum, *Cke.*	Glen Frome,	Dec. 1880.
771.	Nemaspora crocea, *P.*	Bridge Yate,	Sept. „
772.	Puccinia graminis, *Pers.*	Cotham,	Mar. 1881.
773.	„ primulæ, *Grev.*	Goblin Combe,	July, 1880.
774.	Ustilago carbo, *Tul.*	Sandford,	July, „
775.	„ longissima, *Tul.*	Cheddar,	July, „
776.	Trichobasis Ulmariæ, *Cooke.*	Portbury,	July, „
777.	Æcidium valerianacearum, *Duby.*	Near Ashton,	May, „
778.	Æcidium primulæ, *D. C.*	Westridge Wood,	May, „
779.	Epicoccum neglectum, *Desm.*	Clifton,	June, „
780.	Cladosporium herbarum, *Lk.*	Cotham,	Mar. 1881.
781.	Coccotrichum brevius, *B.&Br. Ann. Nat. Hist.*, No. 1918	Leigh Wood,	Dec. 1879.
782.	Dactylium roseum, *Berk.*	Clifton,	Sept. 1880.
783.	Fusidium album, *Desm.*	Leigh Wood,	Nov. „
784.	Botryosporium pulchrum, *Corda.*	Clifton,	Feb. 1881.
785.	Acrostalagmus cinnabarinus, *Corda.*	„	Aug. 1880.
786.	Erysiphe lamprocarpa, *Lev.*	Portbury,	July, „
787.	„ tortilis, *Lk.*	Portishead,	July, „
788.	„ communis, *Schl.*	Stapleton Park,	Sept. „
789.	Chætomium elatum, *Kze.*	Clifton,	Aug. „

790.	Peziza leporina, *Batsch.*	Abbots' Leigh,	Sept. 1880.
791.	„ aurantia, *Fr.*	Blaize Castle Wood,	Oct. „
792.	„ humosa, *Fr.*	Leigh Wood,	Oct. „
793.	„ omphalodes, *Bull.*	Stapleton Park,	Sept. „
794.	„ macrocystis, *Cooke.*	Leigh Wood,	Oct. „
795.	„ apala, *B. & Br.*	Mangotsfield,	Sept. „
796.	„ echinulata, *Awd.*	Leigh Wood,	Aug. „

This has frequently been found in this country, but has not hitherto been recorded. (Plate IV., fig. 1.)

797.	Peziza palearum, *Desm.*	Mangotsfield,	Sept. 1880.
798.	„ straminum, *B. & Br.*	Clifton Rocks,	May, „
799.	„ micacea, *Pers.*	Leigh Wood,	July, 1879.

New to Britain.

800.	Peziza (Dasyscypha) fugiens, n. sp.	Mangotsfield, Abbots' Leigh,	June, 1880. Mar. 1881.

Very minute, scattered, sessile, globose, then expanded, thin, tomentose, white; asci oblong or clavate ·001 in. × ·0008 in.; sporidia eight, linear, straight or slightly curved ·0003 in. — ·0004 in. × ·00008 in., obliquely biseriate, so that only four are visible in the ascus. (Plate IV., fig. 2.)

On dead rushes in bogs; probably common, but, as Mr. Phillips believes it to be undescribed, it is named provisionally. The cups seldom exceed ·008 in.

801.	Peziza Curreiana, *Tul.*	Abbots' Leigh,	Mar. 1881.
802.	Helotium flavum, *Klotsch.*	Glen Frome,	1880.

New to Britain. (Plate IV., fig. 3.)

803.	Helotium pallescens, *Fr.*	Leigh Wood,	Nov. „
804.	„ fagineum, *Fr.*	Henbury.	
805.	„ albopunctum, *Desm.*	Leigh Down,	Nov. 1879.

New to Britain.

806.	Ascobolus vinosus, *B.*	Abbots' Leigh,	Mar. 1881.
807.	„ glaber, *Pers.*	Leigh Down,	Jan. „
808.	„ immersus, *Pers.*	Stapleton Park,	Feb. „

809.	Ascobolus (Saccobolus) neglectus, *Boud.*	Leigh Down,	Jan. 1881.
810.	Ascobolus (Ascophanus) argenteus, *Curr.*	Stapleton Park,	Mar. „
811.	Ascobolus sexdecemsporus, *Crouan.*	Abbots' Leigh,	Mar. „
812.	Ascobolus (Ryparobius) argenteus, *B. & Br.*	Leigh Down,	Jan. „
813.	Heterosphæria patella, *Grev.*	Dundry,	May, 1880.
814.	Hypomyces luteovirens, *Tul.*	Leigh Wood,	Aug. „
815.	„ Broomeianus, *Tul.*	Abbots' Leigh, Stapleton Park,	Oct. „ Dec. „
816.	Acrospermum compressum, *Tode.*	Abbots' Leigh,	Mar. 1881.
817.	Nectria erubescens, *Desm.*	Clifton Down,	Oct. 1879.
	On holly leaves. New to Britain. (Plate IV., fig. 4.)		
818.	Dothidea filicina, *Fr.*	Leigh Wood,	Nov. 1878.
819.	Diaporthe ilicina, *Cke.*	Durdham Down,	May, „
820.	Melanconis lanciformis, *Tul.*	Leigh Wood,	April, 1877.
821.	Valsa dissepta, *Fr.*	„	Winter „
822.	Sordaria merdaria, *Fr.*	Leigh Down,	Mar. 1881.
823.	„ minuta, *W. var.* tetraspora. (Plate IV., fig. 5.)	„	Jan. „
824.	Sordaria curvula, *D. By.*	Stapleton Park,	Feb. „
825.	„ pleiospora, *W.* (Plate IV., fig. 6.)	Leigh Down,	Jan. „
826.	„ Winteri, *Ph. & P.*	„	Feb. „
827.	„ bisporula, *Hans.*	„	Mar. „
828.	Xylosphæria hemitapha, *B. & Br.*	Leigh Wood,	Mar. 1880.
829.	Sphæria decedens, *Fr.*	„	Jan. „
830.	„ quadrinucleata, *Curr.*	The Gully,	Feb. „

[redacted]

C Bucknall del ad nat.

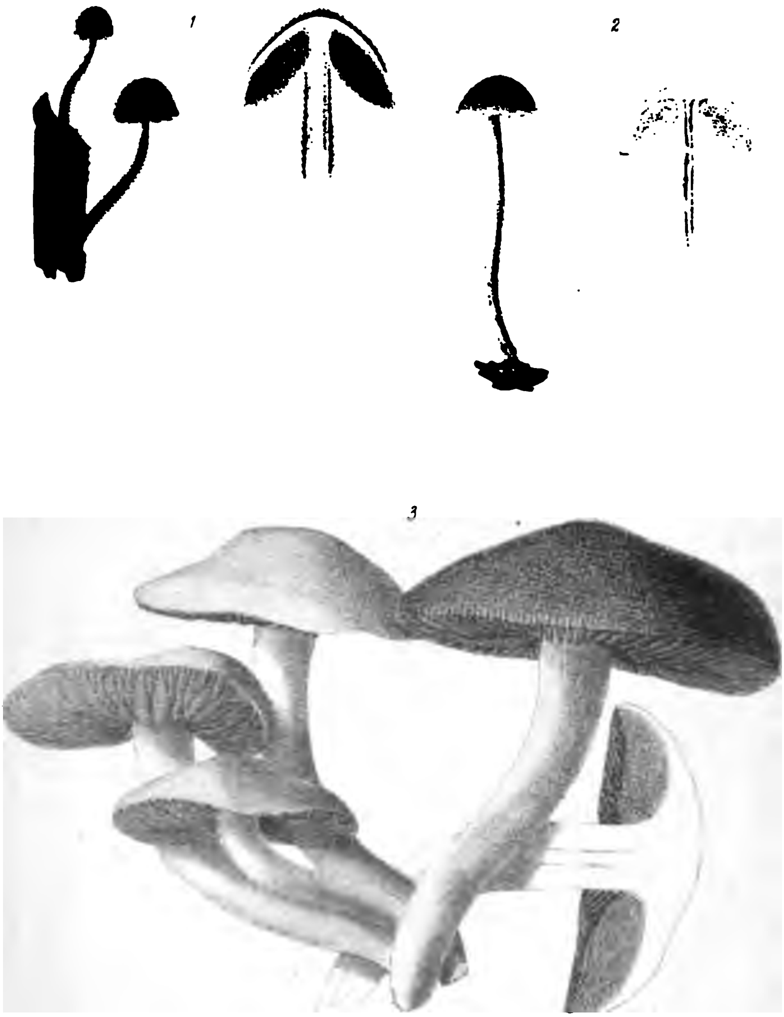
1 Cortinarius firmus, Fr. $\frac{2}{3}$ nat size
2 Agaricus Bucknalli B.& Br.

[redacted]

Plate II.

1. Agaricus granulosus var. rufescens B & Br.
2. " delicatus n. sp. nat. size.
3. " " magnified.

Plate III

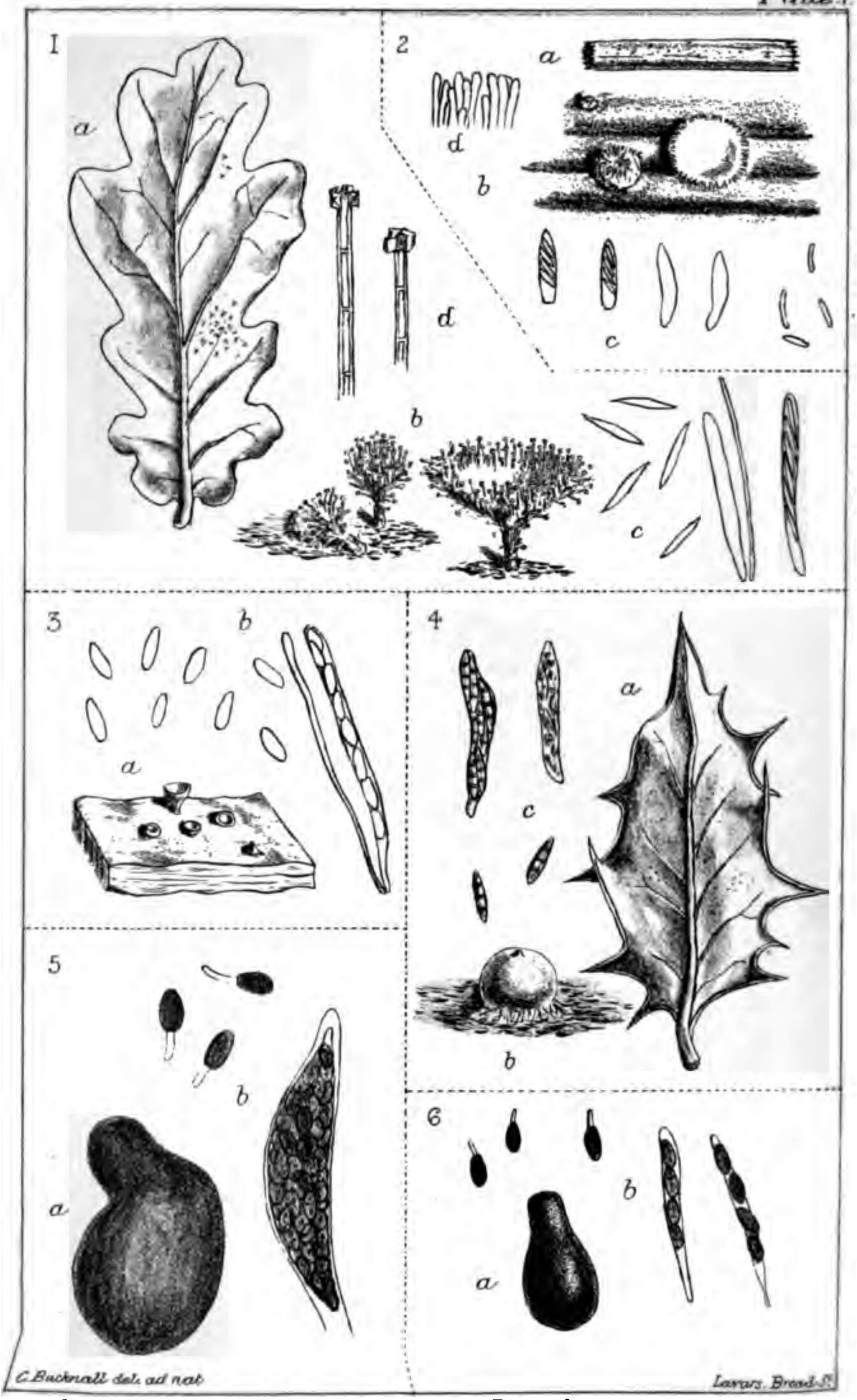


C. Bucknall del. ad nat. — Lavars Bristol

1. Agaricus muricatus var gracilis Oud.
2 " restitus, Fr.
3 " sarcocephalus Fr.

[redacted]

Plate 4.



C. Bucknall del. ad nat. Lavars. Bristol.

1. Peziza echinulata.
3. Helotium flavum.
5. Sordaria pleiospora.

2. Peziza fugiens.
4. Nectria erubescens.
6. Sordaria minuta.

831.	Sphæria scirpicola, *D. C.*	Cheddar,	July, 1880.
832.	„ clypeata, *Nees.*	The Gully,	Feb. „
833.	„ vectis, *B. & Br.*	Portbury,	June, „
834.	„ Michotii, *West.*	Filton,	June, „
835.	„ nardi, *Fr.*	Leigh Down,	Mar. „
836.	„ infectoria, *Fckl.*	Leigh Wood,	Mar. „

DESCRIPTION OF PLATES.

Plate I.

Fig. 1. Cortinarius firmus, *Fr.*
Fig. 2. Agaricus Bucknalli, *B. & Br.*

Plate II.

Fig. 1. Agaricus granulosus, var. rufescens, *B. & Br.*
Fig. 2. „ electicus, *B.*

Plate III.

Fig. 1. Agaricus muricatus, var. gracilis, *Quel.*
Fig. 2. „ vestitus, *Fr.*
Fig. 3. „ sarcocephalus, *Fr.*

Plate IV.

Fig. 1. *a.* Peziza echinulata, *Awd.*
b. Plant × 30.
c. Asci and sporidia × 330.
d. Hairs of cup × 330.
Fig. 2. *a.* Peziza fugiens.
b. Plant × 50.
c. Asci and sporidia × 330.
d. Hairs of cup × 330.
Fig. 3. *a.* Helotium flavum, *Klotsch.*
b. Asci and sporidia × 330.
Fig. 4. *a.* Nectria erubescens, *Desm.*
b. Perithecium × 50.
c. Asci and sporidia × 330.
Fig. 5. *a.* Sordaria pleiospora, *W.*; perithecium × 40.
b. Asci and sporidia × 200.
Fig. 6. *a.* Sordaria minuta, *W.*; perithecium × 40.
b. Asci and sporidia × 200.

Recent Investigations on the Course of Storms.

By G. F. BURDER, M.D., F.M.S.

EVERY one is familiar with the phenomena of a storm, as they appear to an isolated observer at any one spot, where he and the storm may happen to be. A fall of the barometer, a gale of wind, and generally a downpour of rain—these are the chief incidents observed. But the meteorologist, who would contribute anything to the advance of the science, or who would even keep abreast of the advance already made, must look at a storm from quite another point of view. He must take his stand-point (so to speak) outside the storm. He must collect and collate observations of the same storm taken at many different places, with a view to discover the mode in which it originates, to trace its path over the earth's surface, and, by a comparison of the direction of the wind at the same instant in different parts of the area covered by it, to determine the laws which govern the movements of the air within it.

This has been the great work of modern meteorology. It is not yet nearly completed, but it is making very satisfactory progress.

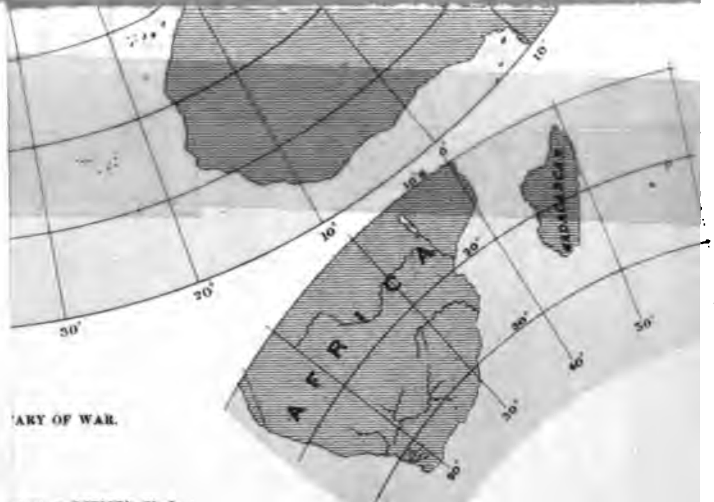
It is not without interest to look back upon the history of this department of meteorology. It has a history of about fifty years.

In the year 1831, Mr. Redfield, of New York, published the results of his investigations regarding the phenomena of West Indian hurricanes. These destructive visitations (to which we

INTERNATIONAL CHART.

Showing Tracks of Centres of Low Barometer for April, 1878.

No. VI.



ARY OF WAR.

SIGNAL OFFICER, U. S. A

have no parallel in our own latitudes) offered an inviting field for inquiry, and it is likely enough that before Redfield's time, many had suspected what it was reserved for him to demonstrate. The very peculiar and striking phenomena observed in places over which the centre of the storm passed—first a hurricane of wind from a certain quarter, then a period of dead calm, and then a hurricane of wind from precisely the opposite quarter to that from which it first blew—these successive incidents must often have suggested the idea of a gigantic whirlwind passing over the spot. Indeed, we have it in evidence, that so long ago as the year 1801, this idea had presented itself to one Colonel Capper, whose observations were made upon similar storms occurring on the coast of Coromandel. Nevertheless the credit belongs to Redfield of having proved by a comparison of actual observations at many different places. that the hurricanes of the West Indies are circular or rotatory storms. He did more than this. He showed that not only was there a gyratory movement of the air within the storm, but that the storm itself—say, the centre of it—moved over the earth's surface in a very definite and determinate manner.

The work commenced by Redfield was taken up by Lieut.-Col. Reid in this country. In the year 1838 Reid published a book on the "Law of Storms." In this he not only confirmed abundantly the conclusions of Redfield with regard to the West Indian hurricanes, but showed also that the typhoons of the China Sea, and those of the Indian Ocean were governed by the same general laws. He also pointed out the remarkable fact, that whereas in the hurricanes of the northern hemisphere the wind circulates in a direction contrary to the hands of a watch, in those of the southern hemisphere the rotation is invariably in an opposite direction. North of the equator the rotation is retrograde; south of that line it is direct. Reid also expresses his belief (as Col. Capper had done before him) that many

of the storms of the temperate latitudes partake of the same nature essentially as the tropical hurricanes.

Since the date of Reid's work, and especially within the last twenty years, a great impulse has been given to the study of this branch of meteorology. Several causes have contributed to this—the establishment of Meteorological Societies in various countries, the multiplication of observers (without whose aid nothing can be done), and, perhaps most of all, the introduction and application of the electric telegraph. The advantage of the telegraph to meteorology has been mainly indirect. For purposes of study the storms of last year are as valuable as those of yesterday, and more so, inasmuch as they admit of the observations being more complete. But what the telegraph has done for meteorology is this. It has created a kind of living interest in the study, and, by holding out the prospect of immediate practical application, it has stimulated the Governments of various countries to organise systems of observation to an extent, which could hardly have been compassed, either by individuals or by societies.

The great meteorological achievement of the last twenty years has undoubtedly been the establishment of the principle, that all great atmospheric commotions, in whatever part of the world they occur, are essentially cyclonic in character—that is, that they partake of the same nature as the so-called cyclones, or circular storms of the tropics. We may even go further than this, and apply the same law to those minor atmospheric movements, which are concerned in the ordinary weather changes with which we are familiar. This becomes obvious enough when we examine an isobaric chart of any considerable tract of the earth's surface. An isobaric chart is a chart, upon which the lines of equal barometric pressure are marked—the isobaric lines, as they are called, or sometimes, for shortness' sake, isobars. One of the most valuable series of charts of this kind that have yet been published, is that constructed by Captain Hoffmeyer, of Copen-

hagen, embracing the whole of Europe, and the North Atlantic Ocean, with parts of Asia, Africa, and America, and representing the chief meteorological elements at a given hour on every day of the year.

Having once mastered the general laws of the wind, the observer of the weather is no longer confined to a knowledge of what is going on at his own post of observation. He sees in his mind's eye the whole system, of which the weather at his own station forms a part. Like the comparative anatomist with his bone, he constructs an entire storm from a mere local fragment. If, for example, he notes a strong S.E. wind, he knows with as much certainty, as if he had telegraphic information of the fact, that a centre of barometric depression lies in the S.W. He has no positive means of ascertaining the distance of this centre, but if he sees his barometer falling fast, he knows that the centre is moving rapidly towards him. Should he observe the wind slowly veer from S.E. to S. and S.W., he will conclude that the centre of the storm is no longer coming towards him, but is passing at a considerable distance in the N.W. If the changes of wind, instead of being slow, are very rapid, he knows that the centre is passing at no great distance from him. If the wind, instead of veering in the ordinary direction, backs from S.E. to E. and N.E. (supposing him to observe in this locality), he infers that the centre is passing up the English Channel or across France. If, as sometimes happens, a dead calm prevails with a low barometer, he judges that he is in the centre of a cyclonic system. In the case of persistent gales such as we have lately experienced,[1] oscillating between S.W. and W., he rightly pictures to himself a succession of deep depressions passing in the far North. In this way, so much additional interest is given to the observation of weather changes, as goes

[1] This paper was read March 4, 1880.

far to compensate the observer for the physical discomfort which these changes often bring.

I have spoken of the movements of a storm-centre with reference to the observer, and this leads me to what is really the nucleus of my subject. Centres of barometric depression (which are also centres of circulating winds) have certain movements of their own, more or less regular and determinate. And this is equally true, whether the centre of depression be the focus of a tropical hurricane, or whether it be the centre of an ordinary Atlantic gale, or whether it be merely the centre of a comparatively languid circulation of air.

The paths of storms over the earth's surface—this is what I propose now to say a few words about. And here we must be careful not to lose sight of the distinction between the path of the storm, and the path of the wind. By the path of the storm we mean the path of the whole storm system, or perhaps we had better say the path of the centre of the storm; for though the whole storm moves bodily, it is clear that the centre is the only part, the movement of which can be accurately traced. The direction of the wind within the area of the storm will of course vary with every point of the circle. Now, the path of the centre of a storm is laid down on a chart, by marking the position on successive days (or at shorter intervals if observations are available) of the point of lowest barometric pressure. A line joining all these points gives the true path of the centre of the storm, or (as we may say) the path of the storm.

It is upon this principle that a chart has been constructed, lately issued from the Signal Office of the United States of America, the salient features of which have now to be explained.[1]

[1] For copies of the chart to accompany this paper, the author is indebted to the courtesy of Major-General Hazen, Chief Signal Officer of the United States.

The irregular and somewhat interlacing lines observed upon the chart, represent the paths of all the centres of barometric depression, which admitted of being traced in the month of April, 1878. I say the paths of the centres of barometric depression, because there is no reason to suppose that all of these centres were centres of actual storms. If a choice existed, one would have preferred a chart of all the great storms of a year to one of all the barometric depressions of a month, for although, as I have already said, there is an essential identity of nature between all depression-centres as regards the circulation of winds around them, it by no means follows that the minor depressions can be taken as types of the major, with reference either to rapidity of movement or to direction of movement. However, we must make the best of the material to hand. Possibly, at some future time, when other charts have been issued, we may have a further opportunity of pursuing the subject.

Let us see, then, what the chart teaches with regard to the paths of storms or of depression-centres.

Notice first the *number* of these lines. There are altogether twenty-two, representing that number of separate depression-centres. There might probably be more in a winter month.

Notice next the *point of origin*. That is very various. Some make their first appearance on the Pacific coast of America, others on the Atlantic coast. Some commence their career at sea, others on land. Several appear to take their origin in the Arctic regions.

The *direction* in which the centres move is a point of special interest. As a rule, and speaking generally, they all move from West to East, but the deviations from a straight course are numerous and large. A common tendency is to take a South-East course at first, and afterwards a North-East course, the result being a curved line with its concavity towards the North.

The *length of course* varies greatly. Some have a very short life. Others retain their identity through a course of many thousands of miles. One originating on the Pacific coast of America traverses the entire American continent, and the Atlantic Ocean.

Lastly, the *rate* at which these centres move is by no means uniform. In the chart we find eight to twelve days occupied in crossing the Atlantic. From other sources there is .reason to believe, that the time occupied may range from three to sixteen or even twenty days.

A number of interesting questions are suggested by a chart of this kind.

What determines, in the first instance, the formation of a centre of depression with winds circulating round it?

What is the causal relation between the depression and the wind? Does the wind cause the barometer to fall, or does the fall of the barometer produce the wind?

Why should storms once formed move from West to East, rather than from East to West?

Why in particular instances should they change their direction or become stationary?

Why should some fly across the ocean with the speed of an express train, while others, not less energetic as regards their internal movements, creep and loiter in their course?

Lastly, what light does the chart throw upon the vexed question of the possibility of predicting European storms from the American side of the Atlantic?

I pass over all these inquiries but the last. On that I have a word to say.

It is well known that some few years ago, the enterprising proprietor of the *New York Herald* instituted a system of storm-warnings, despatched by telegraph from New York to London, and published in the daily newspapers throughout this country.

Opinions are, I believe, still divided as to the success or non-success, on the whole, of these forecasts. There have no doubt been some striking verifications (or coincidences), but I believe there have been a much larger number of conspicuous failures.

At the end of January last, I took the trouble to search the file of *The Times* newspaper for that month, with a view to see how many storms had been predicted from America, and with what success. Now, the month of January last was a month of exceptionally high barometer and settled weather. Excluding a few days at the beginning and end of the month, I found that from the 4th to the 27th inclusive, the daily charts gave no indication of any atmospheric disturbance of any moment in any part of Western Europe. Yet during this same interval no fewer than nine storms were telegraphed from New York as threatening "the British, Norwegian, and French coasts." The contrast between prediction and fact could hardly be more complete. Yet I have no reason to doubt, that the forecasts were the best that could be made. Each of them, we may assume, was based on the occurrence of an actual storm on the American coast, and we know that during a great part of the month, the Atlantic was tossed by tempests of unusual violence. But the inference that these storms would reach Europe was not justified by the event.

Consulting the chart on the practical feasibility of these predictions, we get no conclusive answer, but what answer we get is discouraging.

Of the five depression-centres, which appear on the chart to be crossing the Atlantic, one, turning northward, passed near Iceland, three became exhausted in the neighbourhood of the British Isles; while the only one, which from the length of its European course would seem to admit of prediction, will be found to have had its origin in the Atlantic Ocean.

Professor Loomis, an eminent American meteorologist, has

examined this question with care. He finds, that of the storm-centres which leave the American coast, one in nine passes over some part of England, while one in six comes sufficiently near to occasion a gale.

A very instructive chart, as showing the erratic behaviour which some storms exhibit in their passage across the Atlantic, is published by Professor Loomis in a recent number of the *American Journal of Science*. In this case, the storm-centre, starting from a spot a little distance south of Greenland, and proceeding for some days in a regular easterly course, suddenly turns upon itself, and, after wandering in an aimless manner about the middle of the Atlantic, is found after the lapse of a fortnight at a place not many hundred miles from that, whence it started. Then, as if reminded of its duty, it takes a fresh start, and finally reaches the coast of Norway. A storm such as that must defy accurate prediction.

For the solution of some of the questions which I indicated just now, we may have to wait until observations have been collected and discussed from a wider area than at present. We need observations from southern, as well as northern latitudes, from the Pacific, as well as from the Atlantic. In the meteorological millennium, when we shall have the barometric pressure over the whole world charted for every day in the year, a flood of light will no doubt be thrown upon points which are now obscure, and if the forecasting of the weather should never arrive at the perfection which some anticipate, we shall at least have the satisfaction of knowing the reason why.

A Naturalist's Ramble in Guernsey.

By ADOLPH LEIPNER, F.Z.S.

THIS island, the second of the Channel Islands in point of size, is in the form of an isosceles triangle, its eastern and southern sides being each about seven miles in length; the western, the most indented side, is nearly ten miles long; its area is twenty-three square miles.

The southern portion, which resembles in many respects the south coast of Cornwall, is mountainous, attaining in some parts an elevation of nearly 400 feet above the sea, and forms a plateau, gradually declining to the north about half way across the island; the northern part is flat, diversified by irregular hills of no great elevation. The geological formation of the northern part is Syenite, of the south Gneiss, which is traversed by large seams of hornblende, called in the locality "Trap Dykes." The Syenite, or Guernsey granite, is largely quarried, and forms the principal article of export, not less than 238,345 tons having been shipped in 1879, and a similar quantity the previous year. It is preferred on account of its extreme hardness, and is exported in rough pieces to be broken in England—in spalls ready for Macadamizing, in blocks for pitching, and prepared for kerbs. Valuing it at 6s. per ton, the annual return from this source alone is £70,000.

The export trade of the island is almost entirely confined to England, and includes, beside the granite, vegetables (potatoes,

broccoli, &c.) and fruits (grapes, tomatoes, pears, &c.). Owing to the early spring—vegetation being usually a month in advance of that of England—these products fetch a high price in the English market. Glass is extensively used in raising this produce and in horticulture, and it is no exaggeration to say there are acres of greenhouses. The quantity of grapes exported, all grown under glass, in 1880, is estimated at 200 tons; they fetch in Covent Garden Market from 15s. to 8d. per lb., according to season and quality—estimated value, £20,000. The soil is not naturally of exceptional fertility, yet, owing to the mildness of the winter, two crops are frequently obtained in a year. Seaweed, here called "Wrack," a corruption of "Vraic," is the principal manure. This is cut at low water of spring tides, and collected from the beach after storms; and is also used in the manufacture of iodine, &c. The article is so important, that its collection is regulated by local ordinances; each parish can only cut at its appointed bays, and no one must cut but at the authorized times. The collection of the vraic-harvest is a most animated scene; all the country carts, horses, and labourers are in request, the beach is alive; there are men up to their waists in the sea, cutting the weed from the rock, others collecting it with large wooden rakes, others carrying or carting it to a place of safety above the flood-tide; then at greater leisure it is carted away to the farm, or spread out in odorous patches on the shingle or turf by the roadside along the bays to dry. (I remember the smell arising from it along Vazon Bay, and the blue-eyed children running after the carriage, crying "Des doubles," "Des pennies").

With all its productiveness the islanders cannot raise sufficient food to feed the inhabitants, nor is this to be wondered at when we remember that 30,000 people are here concentrated on twenty-three square miles. The deficiency is largely supplied from France, there being constant communication with St. Malo,

St. Brieux, Cherbourg, and Binic. Manufactured goods come from England; coal from the North. Here we have the apparent anomaly of a place exporting and importing the same articles. But the potatoes exported are early produce, raised in greenhouses and the open fields, and exported before Midsummer, while those imported arrive in November and subsequent months, and are purchased at a quarter of the rate received for those exported. There is a great demand for the island cattle for dairy purposes, both in England and America; a herd was recently forwarded to the latter country by the Great Western Steamship Company—Guernsey cows being a branch of the famed Alderney breed, but excelling in size and equalling in yield of milk the Jersey stock. Alderney itself hardly exports a score in a year. Bullocks have to be imported from France and Spain, and mutton from England. Increasing attention is being given every year to market-gardening, the orchards producing the cider, for which the island was formerly noted, are being rooted up. Small vegetables become in their season important articles of export, *e.g.*, asparagus and radishes—more than 1000 packages of these latter were exported in the week ending March 19, 1881—even parcels of groundsel have paid well for carriage to London.

The country people live very frugally, cabbage soup, "soup à la graisse," is one of the common dishes. The farms are generally cultivated by the owners with very little hired help. The successful result of the island trade is shown in the wealth of the inhabitants. Besides the value of landed estate and house property, there are £240,000 in the Guernsey Savings Bank, about £230,000 invested with the States at 3 per cent., all local capital, large amounts are invested in shipping, and there is an unusually large proportion of English and foreign bondholders. The monetary system is most confusing: the silver currency is French, francs, half-francs, five-francs, &c.;

the only local coins in existence are bronze, doubles, two-doubles, four doubles, and eight-double pieces, called pence, and exactly on par with the French "dix centimes," so that ten eight-double pieces make a franc. The States and two local banks issue notes of £1. Prices are always quoted in shillings and pence, but shillings are non-existent, having to be made up by a franc and two eight-double pieces. English money commands a premium, varying with the exchange on Paris—a sovereign is at present worth a Guernsey pound note, a shilling, and a half-penny. This complicated system is kept up apparently on account of the advantages it offers to the States and shareholders in local banks, who, being persons of influence, can control the action of the States in this matter. A prejudice against French gold is wisely stimulated, so that all who have to pay or receive large amounts are compelled to employ £1 notes, which therefore circulate to a large amount (£90,000). There are few strangers who get to comprehend this complicated system even in a year's residence.

The language is a French patois, but the rising generation evince great desire to acquire English, as their prospects in after life depend greatly on a knowledge of it. In the "Folk-Lore of Guernsey and Sark," by Louisa Lane-Clarke, the Guernsey-French is thus described :—"The language of the townspeople, from their constant intercourse with strangers, is very intelligible English, though spoken with a peculiar accent, and frequently interlarded with the mother tongue; but in the country, or if marketing on a Saturday, when the town is thronged with peasants, the stranger may be greatly puzzled to make out what language the people are talking. It is a good old dialect, which, during the last century at least, has proceeded in a steady course of gathering, like a rolling snowball, from everything it encountered, and increasing its vocabulary by various compounds of Latin, Welsh, Scotch, German, English, and Italian, added to

the original stock, which was Norman-French, making altogether a very expressive and by no means an inharmonious patois. If it *seems* to be rude and harsh, it is because you do not hear it kindly spoken; because, perhaps, you listen to the contentions of the market-place, or the coarse voices on the pier—no language is euphonious in these places."

The inhabitants of the island are excessively exclusive and broken up into cliques; one result of which is, that societies for mutual improvement, such as a Naturalists' Society, are unknown there. This is much to be regretted, as there are few localities where natural history could be studied to greater advantage than here; the area being so small, it could be thoroughly worked, and yet there need be no fear that the materials at command would soon be exhausted.

The varieties of soil are very great, the cliffs, the low sandy sea-shore, and the marsh-land, each produces its peculiar plants: the number of flowering plants, exclusive of sedges and grasses, enumerated in Professor Ansted's work, is 505. The list, though the latest, is notoriously inexact, and requires an authoritative revision. Such a work would fall to a Naturalists' Society, if such existed, and, by putting himself into communication with working members of it, the author would no doubt have been able to enjoy his stay there to a far greater extent, and to produce a much longer list of objects seen and studied. Indeed, had it not been for the most kind attention and valuable assistance of Mr. George Derrick, of St. Peter's Port, even the sight of the most interesting plants in the island—*Cyperus longus*, *Orchis laxiflora*, *Spiranthes æstivalis*—would not have been obtained. *Spiranthis autumnalis* and *Scilla autumnalis* were too widely distributed and far too abundant to have escaped detection; they were to be met with everywhere along the coast in perfection in August; but *Pyrola rotundifolia*, though plentiful where it did grow, was too local, and made a guide almost

indispensable, and even with a guide to the exact locality, *Isoetes Hystrix* might be passed over. The thinness of the soil causes the cliffs and higher sloping grounds to be burned up in summer. The botanist has to wait till October in order to find *Ophioglossum lusitanicum* and *Trichonema Columnæ (R.)* and to see the cliffs on the whole to perfection. It is somewhat tantalizing to see *Agave Americana*, tall *Dracæna*, myrtles planted in the open ground, and fuchsias amongst heaps of stones, and nearly as secure from winter frosts as they are in our greenhouses in England. Skates are not likely to be of use once in five years in Guernsey. It is a rare thing to see snow lying on the ground, and in proof of the mildness of the winters it may be mentioned, that a friend of the author has for nearly twenty years without break never been without primroses in the house, picked from the open fields from December to June. During this last severe winter of 1880-1881 there has been only one heavy fall of snow.

One of the most remarkable acclimatized vegetable productions of Guernsey is *Gunnera scabra*, belonging to the *Araliaceæ*. It is mentioned by Darwin as occurring in Chili, and described by him as attaining there a great size, with stems as thick as a man's leg. But some of the Guernsey specimens are quite as large. In its mode of growth and shape of the leaves it much resembles rhubarb, and indeed the people of the island very generally call it "wild rhubarb." The author saw it in great perfection in Mr. Smith's nursery, and obtained through his kindness two fruiting spikes, which were exhibited at the meeting of the Society. These compound fruiting spikes were pyramidal in form, thirty inches in length and about six inches in diameter at their base; the small orange-red fruits, with which they were covered, gave them almost the appearance of hugh green fir-cones studded over with little red corals. The leaves of the *Gunnera* being from six to eight feet in diameter,

with leaf-stalks as thick as a man's wrist, give the plant altogether a magnificent, almost tropical aspect.

Of all branches of natural history, botany is the one to which most attention has been given. Professor Babington visited the island, and so thoroughly examined it, that there are few districts which can produce so complete and trustworthy a list as Guernsey. Mr. Wolsey and others have worthily followed up his researches, and their success may be judged of by the addition of *Ophioglossum Lusitanicum*; of *Isoetes Hystrix*, by Mr. Wolsey; and *Gymnogramma Leptophylla*, by Mr. Derrick (1877). The island is one of those places which has been spoken of as a fern paradise, but rather on account of their extreme abundance than from the number of varieties. Walls and hedgerows are everywhere crowded with *Scolopendrium*, *Polypodium*, *Asplenium Adiantum-nigrum*, and *Asplenium lanceolatum*. There is ample scope for the lover of lichens, mosses, liverworts, &c., while an enthusiastic searcher for sea-weeds will be delighted with the beautiful and rare specimens to be found in the picturesque rock-pools.

Turning now to the animal productions of the sea, the author, who however only once indulged in the luxury of dredging, and for the rest had to content himself with shore-work, did not notice any great difference between the Devon and Cornwall coasts and the sea around Guernsey. Foraminifera, Sponges, Sertularians, Campanularians, Medusæ, Actinozoa, and similar organisms abounded, also—even in high rock pools on one part of the island—that lovely little coral, *Balanophyllea regia*. Of Echinodermata, the following were obtained and exhibited at the meeting:—*Comatula rosacea*; *Ophiura texturata* and *albida*; *Ophiocoma neglecta*, *granulata*, *bellis*, and *rosula*; *Uraster glacialis* and *rubens*; *Cribella oculata*; *Luidia fragilissima*; *Asterina gibbosa*; *Echinus sphæra* and *miliaris*; *Spatangus purpureus*; *Echinocyamus pusillus* (of Forbes' British Starfishes).

Amongst the Turbellaria found the most curious one was *Nemertes purpurea*, which was kept alive for several days in an improvised aquarium, and its peculiar mode of progression and habits observed. Not the least interesting marine production was a large broken mast washed ashore at Bordeaux Harbour, a little to the north of St. Sampson's, which was found riddled by shipworms, and its lower submerged half covered with Barnacles (*Lepas*) in such masses, as would have more than filled three carts, and the salmon-coloured peduncles of which, 12 to 18 inches long, were twisting and writhing in snake-like fashion as long as the poor creatures were alive.

On the shore, too, especially on the eastern part of the island, one often finds small heaps of Ormer-shells or Ear-shells (*Haliotis tuberculata*), of which the Channel Islands are our nearest station; but these have not been thrown up by the sea, but are the deposits of man, for these molluscs are collected at extreme low water, especially during the highest spring tides in March and April, and brought to market, or enjoyed by the collectors themselves. The few that were obtained among the rocks at low-water at the time to which this account refers (August) were small, but served on that account all the better for the preparation of their most beautiful Odontophores or tongues as microscopical objects.

The waters around Guernsey seem to be particularly rich in Polyzoa, a group of animals in which the author is specially interested. Of the following species collected in Guernsey (named according to Hincks' Monograph of British Polyzoa) not less than 62 were obtained in the one dredging operation between Guernsey and Herm, of about four hours' duration, referred to above, and were brought home dried, for the purpose of identification. The remaining nine species are only a few of those that were gathered along the shore, and mounted for the microscope with their tentacles extended—the rest, refusing to be

charmed into a display of their beauty, were thrown away and remain unrecorded :—

1. *Aetea anguina*
2. ,, *recta*
3. *Alyonidium hirsutum*
4. *Amathia lendigera*
5. *Beania mirabilis*
6. *Bowerbankia imbricata*
7. *Bugula avicularia*
8. ,, *flabellata*
9. *Caberea Boryi*
10. *Cellaria fistulosa*
11. *Cellepora pumicosa*
12. ,, *ramulosa*
13. *Chorizopora Brongniartii*
14. *Cribrilina figularis*
15. ,, *Gattyæ*
16. ,, *punctata*
17. ,, *radiata*
18. *Crisia cornuta*
19. ,, *denticulata*
20. *Diastopora obelia*
21. ,, *patina*
22. ,, *Sarniensis*
23. *Flustra foliacea*
24. ,, *papyracea*
25. *Flustrella hispida*
26. *Hippothoa divericata*
27. ,, ,, var. *carinata*
28. *Lepralia foliacea*
29. ,, *Pallasiana*
30. ,, *pertusa*
31. *Lichenopora hispida*
32. *Membranipora Dumerilii*
33. ,, *flustroides*
34. ,, *pilosa*
35. ,, ,, var. *dentata*
36. ,, *solidula*
37. ,, *spinifera*
38. *Membraniporella nitida*
39. *Micropora coriacea*
40. *Microporella ciliata*
41. ,, ,, var. *personata*
42. ,, *Malusii*
43. ,, *violacea*
44. ,, ,, var. *a.*
45. *Mucronella coccinea*
46. ,, *Peachii*
47. ,, *variolosa*
48. *Pedicellina cernua*
49. *Phylactella collaris*
50. ,, *labrosa*
51. *Porella concinna*
52. ,, *minuta*
53. *Rhynchopora bispinosa*
54. *Schizoporella auriculata*
55. ,, *biaperta*
56. ,, ,, var. *divergens*
57. ,, *Cecilii*
58. ,, *discoidea*

59. *Schizoporella linearis*
60. „ *spinifera*
61. „ *unicornis*
62. *Schizotheca fissa*
63. *Scrupocellaria scrupea*
64. *Smittia cheilostoma*
65. „ *Landsborovii*
66. *Smittia reticulata*
67. „ *trispinosa*
68. *Stomatopora granulata*
69. „ *Johnstoni*
70. *Tubulipora flabellaria*
71. *Vesicularia spinosa.*

What a rich harvest might not be gathered in by a Zoologist, who could afford the rather expensive luxury of dredging, aided by such local knowledge as a "Guernsey Naturalists' Society" might and would possess! May the time be not far distant when such an Association is formed not only in Guernsey, but in Jersey too! Besides giving such aid to visitors, as may be desirable and desired, how much would not the members of it enrich their own lives by the acquisition of knowledge and the cultivation of improved social relations!

Rainfall at Clifton in 1880.

BY GEORGE F. BURDER, M.D., F.M.S.

TABLE OF RAINFALL.

	1880.	Average of 33 Years.	Departure from Average.	Greatest Fall in 24 Hours.		Number of days on which ·01 in. or more fell.
				Depth.	Date.	
	Inches.	Inches.	Inches.	Inches.		
January ...	0·658	3·325	−2·667	0·314	18th	7
February ...	4·519	2·260	+2·259	0·899	18th	21
March ...	2·639	2·223	+0·416	1·361	2nd	9
April ...	2·397	2·130	+0·267	0·485	18th	14
May ...	1·244	2·408	−1·164	0·317	27th	8
June ...	2·447	2·563	−0·116	0·370	20th	17
July ...	4·831	2·861	+1·970	0·316	22nd	18
August ...	0·409	3·466	−3·057	0·170	7th	5
September...	3·661	3·423	+0·238	0·310	12th	12
October ...	5·997	3·728	+2·269	1·722	4th	14
November...	3·095	2·698	+0·397	0·589	15th	14
December ...	5·476	2·737	+2·739	0·762	14th	18
Year ...	37·373	33·822	+3·551	1·722	Oct. 4th	157

Remarks.—The rainfall of 1880, although less than that of any year since 1874, was still considerably above the average. Speaking generally, and without regard to intermediate droughts, it may be said that a rainy period has prevailed now for nine years. During this long term there has been but one year (1873) in which the rainfall was not above the average of 28 years, and the aggregate excess in the whole period has been upwards of 44 inches. So marked and long-continued a deviation as this from the normal state of things can hardly be without some important consequences.

Notwithstanding the generally rainy character of the year 1880, two of its months, January and August, were distinguished by an exceptional degree of dryness. January, with 0·658 inch, was the driest January since 1855, and was the more remarkable as following three months of unprecedented dryness at the end of the previous year. August, with 0·409 inch, was by a long way the driest August that has been observed at this station. May was also a very dry and fine month; as March would have been too, but for a heavy downpour on its second day. Three weeks passed in March with scarcely a drop of rain, and 34 days in April and May with less than two-tenths of an inch.

The wettest months of the year were October and December, the former yielding close upon six inches, the latter nearly five and a half inches.

Three times in the course of the year the diurnal fall exceeded an inch, namely, once in March and twice in October. The heaviest fall in 24 hours was on the 4th of October, 1·722 inch.

Snow fell on the 13th of January to an average depth of four inches, and this was the only snowstorm of importance throughout the year.

Reports of Meetings.

GENERAL.

THE first meeting of the year was held on the evening of January 1st, when a paper was read by Professor Thompson on "Hearing with Two Ears." The conclusions arrived at by him were illustrated by various experiments with telephones. The subject attracted a considerable number of visitors as well as members, and the paper appears in full in the foregoing pages.

The next meeting occurred on the evening of February 5th, when Mr. Chas. Jecks contributed a paper, entitled "A Few Thoughts on Darwinism," which will also be found in the present Part.

Professor Sollas followed with his paper on "Evolution in Geology," in treating of which he commenced by stating the views held by the earliest sect of geologists, viz., the Catastrophists, who asserted that all changes in the crust of the globe were the result of convulsions of nature; the granite having been formed from the molten earth, and the strata, according to them, deposited in regular succession. As directly disproving this theory, Mr. Sollas referred to the interruption of the strata along the river Avon. Next come the Uniformitarians, who attribute geological changes to the action of water: the rain corroding the earth's surface, and sweeping the *débris* into the sea, while the waves gradually disintegrate the coast. Denuda-

tion and deposition are thus the two great processes at work in altering the earth's surface. The Uniformitarians were succeeded by the Evolutionists, who ascribe the changes to physical causes, the sun being, as it were, the mainspring, which sets the machinery in motion, causing rain, wind, and other meteorological phenomena, all which are factors in the forces at work. The heat lost by the earth may in great part account for the elevations and depressions on its surface, owing to the difference in the rate of contraction between the interior and exterior. Sir W. Thomson has calculated that it is between 100 and 200 millions of years since the earth began to consolidate; the geologists assign from 50 to 500 millions of years as the period. As we go back to the past, we must naturally expect that the forces at work were more powerful, owing to the increased temperature; and as a proof of this, we find that in layers of equal thickness in the Palæozoic and Tertiary rocks, we have the proportion of extinct species, as one in the former, to four in the latter, owing to difference in the rate of deposition; and the conclusion arrived at is, that the decreasing energy of the sun and earth, must have led to diminishing rapidity in the action of the main factors in geologic change, viz., denudation, reproduction, and elevation and depression of strata.

At the following meeting on the evening of March 4th, Mr. W. J. Fuller's paper on "The Breathing Apparatus of certain Aquatic Larvæ" was read by the Hon. Secretary in the author's absence. This communication appears in this year's Proceedings. Dr. Burder also gave the result of "Recent Investigations on the Course of Storms," which, illustrated by some excellent charts executed under the auspices of the United States Government, will be found in the preceding pages.

At the meeting on the 8th of April, Mr. Leipner read the following paragraphs from the *Natal Colonist* of March 2nd, 1880:—

ANTIDOTE FOR SNAKE BITES.

The *Beaufort Courier* has been favoured by a respected correspondent with an interesting paper on snakes, containing notes on the puff-adder, springslang, hornsman, and the night-adder. The author maintains that Ipecacuanha is an infallible antidote against the bites of all venomous reptiles, and relates the following incidents in support of his view:—"I soon discovered that a more reliable antidote was necessary for persons out of the reach of medical assistance; and as my attention was drawn to the subject by something I read in an Indian newspaper, I resolved to give Ipecacuanha a fair trial, and soon discovered that I was in possession of the desired antidote. I will here relate a little of my experience in the use of this medicine. The first time I tried it was on a boy stung by a scorpion, and I found it cured him in about half an hour. The next case was a woman bitten in the back by a puff-adder. The wound was close to the spine, and received while sleeping at noon. She also recovered. Since then, I have cured people suffering from bites from many kinds of snakes and venomous reptiles, and have not known it to fail in a single instance. One of the most remarkable cures effected by the use of Ipecacuanha powder I will here relate. A reaper on a neighbouring farm was taking a nap at noon, under a shady tree, and a puff-adder came and lay alongside of him. As he woke he pressed against his unwelcome companion with his elbow, and in return received a severe bite in the fore-arm. The farmer not knowing what to use, dispatched a messenger on horseback for advice. Under the impression that it would be too late to apply the remedy in the shape of poultice, I mixed about two teaspoonsful of powder in a pint bottle of water, and told the bearer of it to let his master give it by table-spoonsful until he had used the whole of it. On his arrival with the medicine, it was discovered that the man was lock-jawed, and to all appearances in a dying state. The farmer, however, had the presence of mind to force his jaw open with an iron spoon, and give the medicine by spoonsful. During the evening it began to take effect, and by eight o'clock in the morning the man was able to walk abroad, and take his breakfast, and a

speedy recovery followed. The following is the best mode of using this invaluable antidote:—Mix a tea-spoonful of Ipecacuanha with a little cold water; then scarify the part bitten (making two or three cuts through the skin), and apply the same as poultice. This should be followed by about thirty grains in a wine glass of cold water as an emetic; and, if necessary, both may be repeated in half-an-hour. But this is seldom required to complete the cure, as the pain generally ceases in less than this time, and appetite and health speedily follow." As this is a simple remedy, and is to be found in every farmer's "huis apotheek," I hope this notice will be of service to some unfortunate individuals who are beyond the reach of medical aid.

SINGULAR ENCOUNTER BETWEEN A RINGHALS AND A CROW.

An English farmer living near the border of Tembuland, and not more than three hours from Dordrecht, had occasion recently to take a ride into the veldt, some distance from his homestead, when his attention was drawn to a flock of some twenty or thirty crows who were assembled together near a large heap of stones, and who appeared, from the loud "caw-cawing" and flapping of wings made by them, to be greatly excited about something. On top of the pile of stones one of the crows was engaged in a deadly contest with a snake of the "ringhals" species, about three feet in length. The reptile appeared to be acting on the defensive, and the crow made occasional fierce onslaughts upon his adversary, his object appearing to be to get a good hold of him by the back of the neck; but although the snake showed innumerable marks upon his body, testifying to the sharpness of the bird's beak, he for some time guarded his neck so well that the other could not succeed in his manifest desire. The farmer stood watching the novel contest for the space of some twenty minutes, and the other crows appeared also to take a great interest in the affair, although they did not offer to interfere, no doubt considering that it would not be fair towards his snakeship for any more of their number to take part against him. The snake seemed by this time to be almost exhausted, and

although he made some gallant efforts to get a chance of inserting his fangs in the body of the crow, the latter was too wily for him, and dodged about in such a manner as to avoid his every attempt. At last the reptile (who was standing upon his tail during the fight) suddenly fell down from sheer weakness, when the crow immediately made dart upon its opponent, seized him by the neck, bore him to a great height in the air, and then allowed him to drop upon the very heap of stones whereon the combat took place. The bird then quickly returned, and repeated the manœuvre over and over again, until the snake was quite dead. He then rejoined his companions, when they took their departure together, after having first set up a great "caw-caw," which the birds repeated three times, and which was evidently intended to answer the purpose of three cheers, given in token of victory. Our informant tells us he never saw a snake battered and bruised in such an unmerciful manner as this one was; it was beaten out of all shape, and the poor ringhals' own mother would not have recognised her son had she seen him in such a sad plight.—*Frontier Guardian*, February 6, 1880.

Mr. Leipner then proceeded to give the following paper on "Corals and Coral Reefs":—This substance is produced by vegetable and animal organisms. As an instance of the former, we find certain varieties of seaweed, such as corallines, which secrete carbonate of lime. These, though sometimes classed as corals, are properly, seaweeds. In the animal kingdom there are two sub-kingdoms, the Coelenterata and Molluscoida, which include the true coral-builders. The latter of these are cylindrical in form, and externally resemble Hydra; the tentacles are ciliated for the purpose of producing currents in the surrounding water, and thus assisting in respiration and feeding. They possess perfect muscular, digestive, and nervous systems. In the Coelenterata we have Hydrozoa and Actinozoa, the latter of which possess the greater interest. The body in them is divided into compartments by six membranes, and between these again others intervene, so that the interior cavity is subdivided into a

series of cells or chambers, the total number of which is a multiple of six. It is a remarkable circumstance that among the corals which exist in the Palæozoic formations we find none with six divisions, four being the number. It is within the septa that the coral is deposited, the animal growing upwards as the formation proceeds. Reproduction takes place by budding, an instance of which Mr. Leipner described as having occurred under his eye in the case of a coral in an aquarium. Budding may take place in a four-fold manner—from the base, side, margin, or from the disc itself. The area in which reef-building corals occur is limited. They require for full development a temperature ranging between 70 and 85 degrees Fahr., and the extreme depth must not exceed 20 fathoms. The distribution is not uniform, but it is in the Central Pacific Ocean that we find reefs of the greatest extent; while in the Atlantic and other quarters of the globe they vary considerably in size, according to the nature of their surroundings; the formation of coral being checked by the cold Antarctic currents, fresh water, and the *débris* brought down by rivers. Branch coral grows more rapidly than the massive variety. In the case of a sunken vessel, over which the deposit had gradually formed, it was found to increase at the rate of 3 in. per year. Want of time prevented Mr. Leipner from entering upon several other points connected with the subject, and at the close a unanimous vote of thanks was accorded him for his very interesting and instructive communication.

On October 7th, the Society met, when Mr. Leipner gave, as the result of his holiday tour, "A Naturalist's Ramble in Guernsey," which appears in full in this part of the Proceedings.

On November 4th, Professor Thompson exhibited his new Phonautograph, which is fully described by him in the preceding pages. He was followed by Professor Sollas on "Siliceous Skeletons, and their Mineral Transformations." He commenced

with the consideration of sponges, the skeletons of some of which are directly related to the subject he was about to discuss. In certain varieties of sponge we find the framework arranged in the form of lattice-work, filled up with cubical meshes. Of these we meet with several varieties, such as the Lithistid, the skeleton of which is made up of spicules composed of four rays, terminating in botryoidal expansions, which interlace with one another. In addition to them, there are Hexactinillid and Renierid sponges, the latter of which have skeletons composed of sheaths containing numerous fibres resembling fine needles. All these consist mainly of silica. Among fossil sponges are some, which we cannot find among those at present existing, and *vice versâ*. In the former we frequently find silica replaced by carbonate of lime, an instance of which was produced by Professor Sollas as occurring in a specimen sent to him from the green sand at Folkestone. The formation of flint is intimately connected with the existence of sponge, arising as it does from the deposition of sponge spicules, which we find in all flint. In order to account for such transformation, we must admit that, in some stage of the process, the silica becomes more or less soluble; and to explain this solubility, some writers have framed the hypothesis that it is due to humic acid, which certainly might produce the effect; but this acid has not as yet been proved to exist at the bottom of the sea. That ordinary flint is to a certain extent soluble, is shown in the case of flint walls, where we find the freshly-exposed black surface of the flint gradually disappearing, and leaving behind a white, chalky deposit. Professor Sollas was inclined to attribute the solubility to the great pressure existing at considerable depths, aided by the peculiar action of spiculin, an active principle contained in the spicules. But the subject is still involved in doubt.

The last meeting of the year took place on the evening of December 2nd, when Mr. J. W. White gave "Remarks on the

Formation of a Local Flora"; and Mr. Oliver Giles an account of "The Glacial Boulders of Bromsgrove, Worcestershire": both of which papers have been printed in the Society's Proceedings.

GEOLOGICAL SECTION.

THIS Section held the usual meetings, but of the papers read at them, the only one suitable for publication was that by Prof. Sollas, which has already appeared in another publication.

ENTOMOLOGICAL SECTION.

ALTHOUGH this Section met regularly, the communications contained nothing suitable for insertion in the Proceedings.

BOTANICAL SECTION.

IN contrast with the experience of the previous season, when the weather was unpropitious in the extreme, the Saturday excursions during this summer have been notably successful.

The attendances were large; and although the number of visitors usually present did not permit the members of the Section to apply themselves closely to botanical investigation on every occasion, yet many valuable observations were recorded. It is believed that the popularity of these excursions with the public is one evidence of that increasing interest in scientific matters which is one of the signs of the times, and which, it may be anticipated, will, as a minor result, afford much additional support to the Society.

Subjoined are jottings by the Hon. Secretary of a few of the most interesting of these excursions.

April 10th, 1880.—Present, six members of the Section and eight visitors. Took the private road from Beggar's Bush Lane which leads by a farmstead towards the Abbot's Pond; turned to the left before reaching the latter, and arrived at Failand Farm. In a pasture here Daffodils grow in great abundance, and were now seen in perfection. This is the only good habitat near Bristol, and the party halted to gather the flowers. At this spot the spring-flowering form of *Colchicum autumnale*, discovered by the Secretary in March, was pointed out, being still in blossom here and there among the Daffodils. It was observed that in the adjoining field, where Colchicum abounded, flowers were entirely absent, and that the plants had developed leaves to the extent usual at this period, whereas at the spot where flowers occurred but few leaves were to be seen, and those just peeping above the soil. Close by grew *Polygonum Bistorta* in plenty, and a little beyond the farm some fine plants of *Lathræa squamaria* were very welcome. Here also *Viola hirta*, *V. Reichenbachiana*, and *Chrysosplenium oppositifolium* were noted. The party now turned into the lane running south, and walked a short distance in that direction to visit a luxuriant colony of *Helleborus viridis*, located in a stony field, which at a remote date may possibly have been an orchard. Retracing our steps, a return was made

around the Failand House Estate, where were one or two birch trees in a remarkable state of prolification. Home by the Tan Pits, Sandy Lane, and Abbot's Leigh.

April 17th.—Present, six members of the Section and eleven visitors. Arrived at St. George's Church about 3 p.m., and proceeded through the market gardens to the Avon. Found *Lamium amplexicaule* under a wall at Crew's Hole. This is almost the sole habitat for the plant in the Bristol district. Ferried across to St. Anne's Wood, and made a long but unsuccessful search for *Gagea lutea*, formerly to be found there, and to look for which was the chief purpose of this excursion. In a cultivated field bordering the wood were growing *Sisymbrium thalianum* (very luxuriantly), *Alchemilla arvensis*, and *Veronica Buxbaumii*, all in plenty. There were here several widely differing forms of *Stellaria media* and a great crop of young Lamb's Lettuce in excellent condition for salads. Returned by Brislington and the Bath Road.

May 1st.—On arrival of the train at Clevedon, the party was found to include eight members of the Section and twenty visitors. Among the latter were Mrs. Lainson and Miss Winter, who with Mr. Jecks were kind enough to direct the excursion during the earlier portion of the walk, and pointed out many objects of interest. *Bartramia pomiformis*, *Pogonatum urnigerum*, *Polytrichum juniperinum*, *Ptychomitrium polyphyllum*, and some other mosses were found. Later on, the profusion of wild flowers in Sir Arthur Elton's woods afforded great enjoyment to many of the party, who occupied themselves in gathering large bouquets of primroses, anemones, and woodrush. Pink and purplish varieties of *Anemone nemorosa* were frequent, and the great luxuriance and plenty of *Luzula sylvatica* and *L. pilosa* added a graceful feature to the scene. The walk was continued over the high ground to Cadbury Camp; and the majority of those present ultimately found their way home by rail from Portbury

Station. A small group, however, walked on to Clifton by way of Failand and Beggars' Bush Lane, reaching home at 8 p.m.

May 8th.—Present, seven members and twelve visitors. Arrived at Cheddar Cliffs, 1.45 p.m. The first acquisition was *Ranunculus pseudofluitans*, gathered in the river below the mill, where it was abundant. Passing into the gorge the party separated. Messrs. Giles, Waterfall, and the Secretary ascended the cliffs to the right, while the rest proceeded, some up the the road, and the others to the slopes on the left. The botanists named spent several hours in exploring the upper ledges and rocks on their side of the cliffs. The plant most conspicuous at this early season was *Cochlearia officinalis*, flowering in profusion. *Dianthus cæsius*, now coming into bud, was noticed in its accustomed haunts; but a careful search for *Meconopsis cambrica* did not result in the discovery of a single specimen. *Potentilla verna*, *Myosotis collina*, *Hieracium cæsium*, *Hippocrepis comosa*, *Alchemilla vulgaris*, with the root leaves of *Campanula Trachelium*, and the Cheddar *Thalictra*, were successively recognized. *Carex præcox*, *C. glauca*, and *C. pulicaris* represented the sedges, and the beautiful spikes of *Orchis mascula*, large and abundant, bravely set forth the glories of Orchidaceæ. The Limestone Polypody, as usual, clothed many of the "screes," and *Asplenium Trichomanes*, with *Cystopteris fragilis*, were not unfrequent in more retired and sheltered situations. Descending at length through the fir plantations, Mr. Giles left his comrades and returned to the railway station. It remained for the two others to make the best discovery of the day, for, in a last hunt for *Meconopsis* on some grassy ledges under the high cliffs, Mr. Waterfall fortunately came upon *Saxifraga hypnoïdes*, festooned in mat-like masses on the moist declivity.

May 22nd.—Present, seven members and twenty-six visitors. This large party made its way to Dundry across the fields, passing through Ashton Park, and over the road at the Smythe

PHYSICAL AND CHEMICAL SECTION.

THE meetings of this Section held during the year, and the papers read at them, were as follows:—

January 29th, 1880.

MR. A. M. WORTHINGTON, M.A.—"On the Splash of a Drop."

April 27th, 1880.

PROF. W. RAMSAY, PH.D.—"On the Cohesion of Liquids."

DR. G. S. THOMSON.—"On some Applications of Balmain's Luminous Paint."

November 3rd, 1880.

E. WETHERED, ESQ., F.G.S.—"On the Chemical Action of Carbonaceous Matter on Carboniferous Rocks."

MR. M. W. DUNSCOMBE.—Exhibition of some new forms of Kaleidoscope.

PROF. S. P. THOMPSON.—"Further Researches on the Illusions of Complementary Subjective Motion."

November 26th, 1880.

F. J. FRY, ESQ. (The President).—Exhibition of Tubes shewing Phosphorescent Phenomena and Molecular Shadows.

PROF. S. P. THOMPSON.—"Some Experiments on Induction."

J. G. GRENFELL, ESQ., M.A.—"On the Supersaturation of Chlorate of Potash."

PROF. S. P. THOMPSON.—"On a System of Electric Clocks."

December 10th, 1880.

F. J. FRY, ESQ.—"On Lord Rayleigh's Colour Combination Discs."

PROF. W. RAMSAY.—"On the Determination of Specific Volumes."

MR. D. ORME MASSON, M.A., B.Sc.—"On the Specific Volume of Phosphorus in the Free and Combined States."

NEW SERIES, Vol. II. (1877-8-9).

PROCEEDINGS

OF THE

BRISTOL

NATURALISTS' SOCIETY.

"*Rerum cognoscere causas.*"—VIRGIL.

BRISTOL:
T. KERSLAKE & Co.

PRINTED FOR THE SOCIETY BY W. C. HEMMONS, ST. STEPHEN'S AVENUE.

MDCCCLXXIX.

FLORA

OF THE

BRISTOL COAL-FIELD.

EDITED (FOR THE BRISTOL NATURALISTS' SOCIETY) BY

JAMES WALTER WHITE,
Hon. Secretary of the Botanical Section.

"*Rerum cognoscere causas.*"—VIRGIL.

PART I.

THALAMIFLORÆ.

BRISTOL:
JAMES FAWN & SON.

PRINTED BY E. AUSTIN & SON, CHRONICLE OFFICE, CLIFTON.

MDCCCLXXXI.

EXPLANATORY NOTE.

IN introducing to the reader the first instalment of the new local Flora which has been undertaken by the Bristol Naturalists' Society, a few words from the President may serve to explain both the origin of the work and the method in which it is proposed to carry it out.

The want of a published Flora embracing the whole of the district known as the Bristol Coal-field, with its wide diversity of hill and dale, wood, river, and marsh, and its great variety of geological formation, has been long felt by the local botanist; and our Society had not been many years in existence before this want found expression in a series of resolutions, which were submitted by Mr. Leipner, the Honorary Secretary, and which pledged the members to undertake the registration of all objects of natural history found within a specified area, with a view to publication. These resolutions were adopted by the Society so long ago as the year 1864, but, although considerable progress has been made in other departments of natural history, it was not until about two years since that any systematic attempt was made to collect materials for a Phanerogamic Flora. In the spring of 1879 a programme of weekly excursions was organised by the Botanical Section of the Society, with the definite object of acquiring such a knowledge of the Botany of the district as might justify the publication of a Flora. These excursions have been continued in each succeeding year, and have been useful in keeping up a general interest in the work; although, necessarily, the chief labour has fallen upon a very few individuals. To the Honorary Secretary of the Botanical Section, who edits the publication, the Society is especially indebted.

The area chosen by the Society for the botanical, as for the other fields of research and registration, is that adopted by the

late Mr. William Sanders in his geological "Map of the Bristol Coal-fields and country adjacent." It extends to different distances in different directions. In a northerly and north-easterly direction it includes Berkeley, Dursley, and Wotton-under-Edge; south-eastward, it takes in Bath; southward, Shepton Mallet and Wells; while in a south-westerly direction it reaches as far as Huntspill, which is twenty-four miles distant from Bristol. Altogether, it comprises (roughly) about 700 square miles.

A work embracing so large an area, and the preparation of which has extended over so short a time, must necessarily be incomplete, especially in its earlier portions. It is believed, however, that it will be found to be accurate.

It is intended that a portion of the work shall be published with each annual Part of the Proceedings of the Society until it is complete. The instalment now presented contains Thalamiflorals; the second will contain Calyciflorals; the third, Corollifiorals; the fourth, Apetalous Plants; and the fifth and last, Endogens, Gymnosperms, and Vascular Cryptogams.

The arrangement and nomenclature used are almost entirely those adopted by Professor Babington in the seventh edition of his "Manual of British Botany."

Although bound up with the Proceedings, the Flora will be paged independently, with a view to the ultimate collection of the several parts into a single volume.

The help of botanists residing within the district is solicited, that the work may be as complete as possible. Information of omissions in any published part will be gladly received by the Editor, and will be recorded in a supplementary list.

Certain abbreviations used in the Flora require explanation. The capital letters G. and S. indicate the counties of Gloucester and Somerset respectively. The Roman numerals denote the months in which the plants have been found in flower.

JUNE, 1881.

PHANEROGAMIA.

Class 1. *DICOTYLEDONES.*

Div. 1. *THALAMIFLORÆ.*

RANUNCULACEÆ.

CLEMATIS, *L.*

1. **C. Vitalba,** *L.* *Old Man's Beard, Traveller's Joy,* "because of its decking and adorning the ways and hedges where people travel," *Gerarde,* p. 886.

Native; frequent throughout the district, though mostly on calcareous soil. It appears to prefer submaritime situations. VII.—IX.

THALICTRUM, *L.*

2. **T. minus,** *L.* *β.* (*T. montanum, Wallr.*)

Native; on limestone rocks, very local. Grows plentifully on the Cheddar Cliffs. It occurs also in the vicinity of Clifton, where we believe it to be native. Here, however, it shows no inclination to spread and become plentiful, a few plants only having been observed at any time. It was first recorded in the Bristol habitat by Sole about 1786, and has been gathered there by Mr. T. B. Flower, who possesses Sole's manuscript containing his record. Mr. G. H. K. Thwaites also found it many years ago. as did Mr. C. B. Dunn in 1875. Two plants were known to exist in 1880. VI.—VII.

3. T. minus, *L.* γ. *(T. flexuosum, Bernh.)*

Native; at Cheddar, where it has undoubtedly been found. This view is in accordance with that of Dr. Boswell-Syme expressed in E. B., ed. 3. This is one of the many segregates into which the Linnæan *minus* has been divided. Their history and recognition form one of the most difficult studies afforded by our Flora to the critical botanist.

(*T. saxatile, Schleich.*, has been reported from Cheddar, but probably in error, as is now thought by Professor Babington.)

4. T. flavum, *L.* *Common Meadow-Rue.*

Native; in wet places, not common.

G. Baptist Mills. Stapleton.

S. In plenty by the Avon, opposite Cook's Folly. Long Ashton, Yatton, and the marshes in the Cheddar Valley. VII. VIII.

ANEMONE, *L.*

5. A. nemorosa, *L.* *Wood Anemone.*

Native; in woods and thickets; common, but much more abundant in some localities than in others. III.—V.

ADONIS, *L.*

6. A. autumnalis, *L.* *Pheasants' Eye.*

Alien or colonist; as a weed on cultivated land. Is only of casual occurrence, not being permanently established in this district.

G. Near the old quarry (now filled up), Durdham Down, July, 1855. Specimen in the Stephens' Herbarium from Baptist Mills, no date.

S. Wookey, "one plant yearly for some time," *Miss Livett.* VII.

RANUNCULUS, *L.*

7. R. tricophyllus, *Chaix.*

Native; in ponds and ditches, frequent. The rare form with floating leaves grows in a pond by the roadside near Charfield, G. V. VI.

8. R. Drouetii, *F. Schultz.*

Native; in marsh ditches, rare.

G. Sea Mills.

S. Between Portbury and Weston-in-Gordano. V. VI.

9. R. heterophyllus, *Fries.*

Native; in ponds and streams, rare.

G. Chipping Sodbury. Shirehampton. New Passage. V. VI.

10. R. Baudotii, *Godr.*

Native; in ponds and ditches of brackish water near the estuaries, frequent. V.—VIII.

β. (*R. confusus, Godr.*) Differs so slightly from *R. Baudotii* that it cannot be separated from it except by the length of the stamens.

G. Shirehampton marshes, and ditches east of New Passage. V.—VIII.

11. R. peltatus, *Fries.*

Native; rare and local. The typical plant (*a. vulgaris, Syme's E. B.*) grows in a pool near Yate Station, G. V.—IX.

12. R. floribundus, *Bab.*

Native; more general than the last.

G. Near Chipping Sodbury, Shirehampton, Westbury.

S. Portbury. V.—IX.

13. R. penicellatus, *Hiern.*

A plant which grows in running water, and is abundant in the stream at Cheddar, S., near the mills, must be

placed here. Floating leaves are absent, and those submersed are long with flaccid segments. It is probably *R. pseudofluitans, Hiern.*, which may be identical with *R. peltatus, c. penicellatus* of the Lon. Cat., ed. 7. Another plant with still longer leaf segments is no doubt *d. elongatus* of the same Catalogue. It grows in the river Avon. True *R. fluitans* is not found in the district. V.—VIII.

14. R. circinatus, *Sibth.*

Native; in marsh ditches, locally common.

G. Shirehampton. Stapleton.

S. Very plentiful in the "rhines" throughout the marshlands, extending from Yatton and Weston-super-Mare to Draycot, Highbridge, and Wells. VII.—IX.

15. R. Lenormandi, *Shultz.*

Native; in shallow pools or on mud, rare.

G. Bitton. Shirehampton. VI.—VIII.

16. R. hederaceus, *L.*

Native; in like situations to those of the last species, but more common.

G. Bitton. Hook's Mills. Mangotsfield, near the railway station. Stapleton. Stoke Bishop, extremely local.

S. Ashton Park. Between Abbot's Leigh and Portbury. VI.—IX.

17. R. sceleratus, *L.*

Native; by and in ditches and ponds, not uncommon.

G. Berkeley. Charfield. Hook's Mills. Lawrence-Weston. New Passage. Shirehampton. Thornbury.

S. Draycot. Kewstoke. Long Ashton. Portbury. Yatton. Wookey. VI.—IX.

18. R. Flammula, *L. Lesser Spearwort.*

Native; in swampy places, frequent. It varies greatly in size, habit, and shape of the leaves.

G. Berwick Wood. Filton Meads. Mangotsfield. Stapleton. Yate.

S. Abbot's Leigh. Ashton. Bedminster. Clevedon. Failand. Horrington. Yatton. VI.—VIII.

19. R. Lingua, *L.*

Native; rare and local.

S. In some spots on the moors, as near Clevedon, Walton-in-Gordano, and Yatton. VI.—VII.

20. R. Ficaria, *L. Lesser Celandine; Pilewort.*

Native; very common.

In the herbarium of the Bristol Naturalists' Society there are specimens of an abnormal form of this species, possessing 13 to 18 petals, and 5 sepals. These were gathered at Shirehampton in March, 1868, by the Rev. W. W. Spicer. IV.—V.

21. R. auricomus, *L.*

Native; in woods and shady places, generally distributed. IV. V.

22. R. acris, *L. Meadow Crowfoot; Buttercup.*

Native; in meadows and pastures, very common.

The variation, *a. Steveni,* grows on the sand hills at Weston-super-Mare, and probably elsewhere in the district. VI. VII.

23. R. repens, *L. Creeping Crowfoot.*

Native; in moist places, common.

The primary stem in this species, especially in damp situations, is much more robust, and produces much larger flowers than the flowering shoots thrown up by the runners towards autumn. V.—VIII.

24. R. bulbosus, *L. Bulbous Crowfoot; Buttercup.*

Native; in pastures, &c., common.

A flower of this Buttercup has been observed in which the gynæceum was entirely absent. V.

25. R. hirsutus, *Curt.*

Native; on cultivated land, rare.

G. Lawrence-Weston. Stapleton.

S. Weston-super-Mare.

(*R. parvulus, L.*, is a small few-flowered form.) VI.—X.

26. R. parviflorus, *L.*

Native; in dry places, rare.

G. Baptist Mills. Henbury. Kingsweston. Lawrence-Weston.

S. Bedminster Down, near the three plantations. V. VI.

27. R. arvensis, *L.*

Colonist, though apparently native; only on cultivated land, not very common, but very generally distributed. VI.

CALTHA, *L.*

28. C. palustris, *L.* *Marsh Marigold.*

Native; in marshes and on ditch banks, common.

β. (*C. Guerangerii, Bor.*)

Rare; at Stapleton, G., and Wells, S., whence a good specimen was forwarded by *Miss Livett*, in April, 1880. III.—V.

HELLEBORUS, *L.*

29. H. viridis, *L.* *Green Hellebore.*

Native, or denizen; in stony thickets, and old orchards in many places.

G. The cherry orchard near Westbury. Henbury Combe.

S. The Roman intrenchment in Leigh Wood. In a stony field at Failand. Bourton. Sandford. Wellesley, near Wells. III. IV.

30. H. fœtidus, *L.* *Stinking Hellebore.*

Native; in woods, rather rare.

G. Stapleton Wood.

S. Brockley Combe. Cleeve Combe. Goblin Glen. Churchill. Near Ham Green. Kingswood, near Yatton. Frequent about Bath. III. IV.

AQUILEGIA, *L.*

31. A. vulgaris, *L.* *Columbine.*

Native; in woods and on bushy hills, preferring the limestone; frequent.

G. Durdham Down, in plenty. Westridge Wood, near Wotton-under-Edge.

S. Gurney Slade. King's Wood, near Yatton. Leigh Wood, opposite the Black Rock. Long Ashton, introduced on the G. W. Railway embankment. Portbury. Weston-in-Gordano. V. VI.

ACONITUM, *L.*

32. A. Napellus, *L.* *Monkshood.*

Alien; on river banks and in damp hedges, very rare.

S. A few plants by water in the corner of a copse near Failand Farm, these seemed to have escaped from garden refuse which had been cast near by. On the bank of a stream near Wells, apparently native, *Miss Livett.* Lane in Bourton leading to the Combe, *Miss Winter.* VI. VII.

DELPHINIUM, *L.*

33. D. Ajacis, *Gay.* *Larkspur.*

Alien or colonist. In a sandy field near Kewstoke, S. *T. F. Perkins!* The only record. VI. VII.

BERBERIDACEÆ.

BERBERIS, *L.*

34. B. vulgaris, *L.* *Barberry.*

Native, or denizen; in hedges and thickets. Usually it has been planted where found in this district.

S. Long Ashton. Castle Hill, Clevedon. V. VI.

(*Epimedium alpinum*, *L.*, was found in Leigh Wood many years ago by Dr. Rogers and Dr. Stephens. It was probably an escape, and there is now no sufficient reason for regarding the plant as a Bristol species.)

NYMPHÆACEÆ.

NYMPHÆA, *L.*

35. **N. alba**, *L.* *White Water-Lily.*

Native; in rivers and ponds, frequent.

G. Pool near the railway at Dursley. Henbury. Redland. Shirehampton.

S. Pools near Highbridge. Tickenham Moor. VII.

NUPHAR, *Sm.*

36. **N. lutea**, *Sm.* *Yellow Water-Lily.*

Native; in rivers, ponds, and boggy ditches, frequent.

G. In the river Avon near Hanham. Henbury. In the river Frome near Stapleton. VII.

PAPAVERACEÆ.

PAPAVER, *L.*

37. **P. Argemone**, *L.*

Colonist; in cornfields, very rare.

G. Cornfields near Fishponds. VI. VII.

38. **P. hybridum**, *L.*

Colonist; in cornfields, very rare.

S. Cornfields at Burnham, *Mr. T. B. Flower.* VI. VII.

39. **P. Rhœas**, *L.* *Red Poppy.*

Colonist; on and about cultivated land, very common. VI. VII.

40. **P. dubium**, *L.*

Colonist; in waste and stony fields, and dry places, frequent. We have failed to distinguish *P. Lecoqii*, *Lamotte.*

G. Ashley. Near Combe Glen. Mangotsfield. Stapleton.
S. Clevedon. Dundry. Easton. Knowle. South Stoke. Twerton. Uphill. Very abundant about Weston-super-Mare during the summer of 1880, being then more common than *P. Rhœas*. VI. VII.

MECONOPSIS, *Vig.*

41. M. cambrica, *Vig. Welsh Poppy.*

Native; on the Cheddar Cliffs, S. Now scarce. VI.

GLAUCIUM, *Tourn.*

42. G. luteum, *Scop. Horned Poppy.*

Native; on the sandy shores of the Bristol Channel, from New Passage, G., to Burnham, S., but nowhere abundant. VI.—VIII.

CHELIDONIUM, *L.*

43. C. majus, *L. Common Celandine.*

Denizen; on garden walls, and about farm buildings, rather common. Remarkably luxuriant plants have been observed by a cow yard at Kingsweston, G. It seems as if this plant cannot exist without a good supply of nitrogenous food. Always flourishing where there is house refuse or drainage from farm or cottage, it is most rarely or never to be seen in the open country. V.—VIII.

FUMARIACEÆ.

CORYDALIS, *Cand.*

(*C. solida, Hook,* is reported from near Wells, S., by *Miss Livett.* As an alien, not even naturalized in any part of the country, it must be excluded from our list.)

44. C. lutea, *DC. Yellow Fumitory.*

Alien; naturalized on walls, and about old gardens, frequent.

G. Filton. Henbury. Redland.

S. Brislington. Clevedon. Kewstoke. Long Ashton. Loxton. Milton. Norton. South Brent. Old walls under Dolbery Camp. Common on walls at Wells. Weston-in-Gordano. V.—VIII.

45. C. claviculata, *DC.*

Native; very rare,

S. St. Stephen's Hill, near Temple Cloud. *Mr. T. B. Flower.* VI. VII.

FUMARIA, *L.*

46. F. confusa, *Jord.*

Colonist; on cultivated land, rare.

G. Cornfields near Fishponds.

S. Wells. VI.—IX.

47. F. officinalis, *L.*

Colonist; on arable land, and as a garden weed, common. VI.—IX.

CRUCIFERÆ.

CHEIRANTHUS, *L.*

48. C. Cheiri, *L.* *Wallflower.*

Alien, or denizen; on walls and rocks, rather common.

In great abundance on St. Vincent's Rocks, which are never so attractive as when in the early summer they teem with the fragrance of this beautiful Crucifer. V.

NASTURTIUM, *R. Br.*

49. N. officinale, *R. Br.* *Water Cress.*

Native; in ditches and running water. Very common, and very variable in size and appearance. VI. VII.

50. N. sylvestre, *R. Br.*

Native; on a river bank, very rare.

G. Bank of the Avon at Crew's Hole. VI. VIII.

51. N. palustre, *DC.* *N. terrestre, Sm.*

Native ; on river banks, and in wet places, very rare.

G. Frome Glen, near Stapleton.

S. On a peaty moor north of Shapwick. VII.—IX.

BARBAREA, *R. Br.*

52. B. vulgaris, *R. Br.*

Native; in damp places, common.

A plant differing widely from the type was gathered in the marsh by Stapleton Bridge, June, 1880. Its uppermost leaves were pinnatifid, with a toothed terminal lobe, pedicels and pods long, the latter spreading erect patent. V.—VII.

53. B. præcox, *R. Br.*

Colonist; in dry and rocky places, frequent.

G. Conham. Montpelier. St. Vincent's Rocks. Stapleton.

S. Brislington. South Stoke. Clevedon. V. VI.

ARABIS, *L.*

54. A. hirsuta, *R. Br.*

Native. Frequent on the limestone about Clifton, and on old walls in many places. VI. VII.

55. A. stricta, *Huds.*

Native; on the limestone on both sides of the Avon at Clifton, and at Penpole Point. The only British habitat. This great rarity is to be found in many spots within its limited area, mostly upon the living rock, but sometimes amid débris from the quarries, and in turf. Unfortunately its situations are nearly always easy of access, and we are not aware that the plant has ever shewn a preference for the precipitous portions of the cliffs. Exposed as it is, therefore, to the ravages of plant collectors and thoughtless strangers, it behoves every botanist to do all that in him lies to guard it from destruction. IV. V.

There is an interesting remark in "The British Herbal," by John Hill, M.D., pub. 1756. The author, when writing of the "Daisy-leaved Ladysmock, *Cardamine pumila bellidis folio*," says, "It is common on the mountains in Wales, whence the winds seem to have blown some of its seeds to Bristol; the plant some years being very frequent on St. Vincent's Rock." There is no doubt that Dr. Hill had in mind the *Arabis stricta*, but what other Crucifer he confounded with it is not apparent.

(*A. perfoliata*, *Lam.*, has but a slight claim to be considered a Bristol plant. On the authority of Withering in Turner and Dillwyn's Botanist's Guide it was once to be found on St. Vincent's Rocks, but has certainly not been seen there for very many years.)

CARDAMINE, *L.*

56. C. pratensis, *L.* *Cuckoo-flower.*

Native; in moist meadows, marshes, and on ditchbanks, very common. The flowers are occasionally double (Bishport, S., May, 1880), and in damp seasons some plants develop buds on the leaves, and small bulbs at the base of the stem, as supplementary means of propagation. IV. V.

57. C. impatiens, *L.*

Native; in but one habitat. Abundant on the Pennant at Stapleton, G.; chiefly on the right bank of the river Frome, near the mills. VII.

58. C. flexuosa, *With.* (*C. sylvatica*, *Link.*)

Native; in damp and shady places, common.

Rootstock shortly creeping. Radical leaves few. Biennial or perennial. IV. V.

59. C. hirsuta, *L.*

Native; on walls, banks, &c., very common.

Rootstock none. Annual. Stamens usually four. III. IV.

HESPERIS, *L.*

60. H. matronalis, *L.* *Dame's Violet.*

Alien. A favourite plant in old cottage gardens, and occurs usually as an escape from cultivation.

S. Formerly at Long Ashton, and at St. Anne's Wood, Brislington. Prior Park Woods, 1869. V. VI.

SISYMBRIUM, *L.*

61. S. officinale, *Scop.*

Native; by roadsides, and in waste places everywhere. VI. VII.

62. S. Sophia, *L.*

Native. "Undoubtedly gathered at Burnham, S., in 1869." *Miss Livett.* VI. VIII.

63. S. thalianum, *Gaud.*

Native; on walls, banks, and cultivated ground, rather common.

G. Baptist Mills. Frenchay. Plentiful about Stapleton. St. George's.

S. Clevedon. Ham Green. Pill. Luxuriant in arable fields bordering St. Anne's Wood, Brislington. IV. V.

ALLIARIA, *Adans.*

64. A. officinalis, *Andrzj.* *Garlic Hedge Mustard.*

Native; on hedgebanks, very common. V. VI.

ERYSIMUM, *L.*

65. E. cheiranthoides, *L.* *Worm-seed.*

Native, or colonist. On cultivated or waste ground, and on peat soil in the south of the district; rare.

G. Kingsdown, *Mr. Rootsey's List,* 1828. On walls at St. George's. Stapleton.

S. Bishport. Easton. Brislington. Uphill. In some plenty on Worlebury Hill, near Weston-super-Mare, 1860. Yatton. Near Shapwick.

BRASSICA, *L.*

66. **B. campestris,** *L.* *Swede.*

β. B. Rapa, L. Turnip.

Colonist; on borders of fields and cultivated land, and on river banks. Rather common. VII.

"I am unable to distinguish any constant difference between this plant and *B. Napus,* except that the radical leaves are hispid in *B. campestris* and glabrous in *B. Napus.* Sometimes the hairs on the radical leaves are very few, and confined to the midrib." *Dr. Boswell-Syme.*

(*B. Napus, L. Rape or Cole Seed.* An escape from cultivation. Perhaps not distinguishable from the last. "Whole plant very glaucous, and quite smooth." *Dr. Boswell-Syme.*)

SINAPIS, *L.*

67. **S. nigra,** *L.* *Black Mustard.*

Native; on river banks and in waste places. Frequent, especially on the banks of the Avon. VI. VIII.

68. **S. arvensis,** *L.* *The Common Charlock.*

Native, or colonist. In cornfields, and about arable land generally. Very common. V.—IX.

69. **S. alba,** *L.* *White Mustard.*

Native, or colonist; not so common about Bristol as *S. nigra,* but occurs frequently on cultivated land. VII.

DIPLOTAXIS, *DC.*

70. **D. tenuifolia,** *DC.*

Denizen; on old walls and buildings in Bristol and the vicinity, rare.

G. Horfield. Hotwells. St. Philip's Marsh. Shirehampton.

S. Totterdown. Knowle. VII.—IX.

71. D. muralis, *DC.*

Native, or colonist; abundant about Bristol, Weston-super-Mare, Clevedon, and elsewhere, preferring the coast. This plant is now much more plentiful than it was formerly, and has within a few years greatly extended its area in the West of England. We have both forms or varieties, but the plants are chiefly annual. Occasionally, however, may be noticed a fine biennial or perennial β. *Babingtonii,* probably sometimes mistaken for the last species, but always to be distinguished by the length of the pedicels, and shape of the leaves. VI. VIII.

ALYSSUM, *L.*

72. A. maritimum, *L.*

Alien; naturalized on rocks and in waste places near the sea. An escape from cultivation.

S. Anchor Head Rocks, Weston-super-Mare. Clevedon. VIII. IX.

DRABA, *L.*

73. D. muralis, *L.*

Native; in one spot, very rare.

G. In and about an old quarry at Henbury, where it was discovered by *Miss Powell* about 1846. Still growing there in 1879, but sparingly. IV. V.

74. D. verna, *L. Common Whitlow-grass.*

Native; on walls, banks, and dry rocky places, as on Durdham Down, Bristol; common. III. IV.

COCHLEARIA, *L.*

75. C. officinalis, *L. Scurvy-grass.*

Native; in submaritime situations, and on limestone rocks; very local.

S. Very luxuriant at Weston-super-Mare, in and about the wood, and at Birnbeck. Brean Down. Abundant on the Cheddar Cliffs. V. VI.

76. C. danica, *L.*

Native; on the shores of the Bristol Channel. Has been observed at New Passage, G., and at Weston-super-Mare, S. It may probably be gathered at many other places on the coast, but will not be found inland. IV.—VI.

77. C. anglica, *L.*

Native. Very plentiful on the muddy banks of the New Cut and Avon, at and below Bristol. The Bristol plant differs from that figured in E. B. The pods are shorter and broader, with turgid valves, very much constricted at the replum. We have never found the leaves to be cordate, nor have we seen any specimen which might be thought intermediate in any degree between this species and *C. officinalis.* V. VI.

ARMORACIA, *Rupp.*

78. A. rusticana, *Rupp.* *Horse-radish.*

Alien; though in some spots it has the appearance of a native. Wherever planted it establishes itself tenaciously, and is sometimes found in deserted garden plots, the sole survivor of ancient cultivation. Frequent about Bristol. V. VI.

79. A. amphibia, *Koch.*

Native; by water, rare and local. Reported only from Shirehampton, G., and from both banks of the Avon above Bristol. VI.—VIII.

CAMELINA, *L.*

80. C. sativa, *L.*

Alien; not naturalized, occurring rarely in arable fields. VII.

THLASPI, *L.*

81. T. arvense, *L. Penny Cress.*

Colonist; on cultivated land and near farm buildings, very rare.

G. Cornfields about Horfield, sparingly, but has been gathered in many seasons.

S. Eastwood, Brislington. *Dr. H. O. Stephens.*

VI.—VIII.

82. T. perfoliatum, *L.*

This plant has been reported from St. Vincent's Rocks by *Mr. Salisbury*, and from Montpelier and Ashley, G., by *Dr. H. O. Stephens*, many years ago. We fear it is now lost.

83. T. alpestre, *L.*

Native; on limestone hills, very rare and local.

S. Dry pasture near Sidcot. *Mr. W. B. Waterfall.* On débris from the mines on Mendip, not far from Cheddar. *Mr. T. B. Flower.* Between Shipham and Rowberrow, near Axbridge. *Rev. R. P. Murray, in J. of B.*, 1881, *p.* 174. VI. VII.

HUTCHINSIA, *R. Br.*

84. H. petræa, *R. Br.*

Native; on limestone rocks about Bristol, and also upon walls, very local.

G. St. Vincent's Rocks. Durdham Down. Grows sparingly and of small size only at these habitats, but is very plentiful and luxuriant on walls at Westbury. Blaize Castle. IV. V.

(*Teesdalia nudicaulis, R. Br.*, is recorded in the Phytologist as having been seen at Cheddar, S., but we possess no confirmation of the record.)

LEPIDIUM, *L.*

85. L. Draba, *L.*

Alien; introduced with seed.

G. Cornfields at Stapleton! *Herb. Dr. H. O. Stephens.* Plentiful in St. Philip's Marsh, where it has existed for many years. In the *Stephens Herbarium* Dr. S. notes his fear or belief that the plant had been built out of St. Philip's Marsh, thus making it clear that he had known it there prior to 1846, the date of the memorandum. Roadside at Patchway, June, 1881. V. VI.

86. L. campestre, *R. Br.*

Native; by roadsides and on cultivated land, frequent.

G. Bank of Avon. Berkeley.

S. Henley. Long Ashton. Abundant in cornfields near Portbury. Weston-super-Mare. VI. VII.

87. L. Smithii, *Hook.*

Native; in one spot, perhaps now extinct. On the roadside leading from Shirehampton to the Lighthouse; *Mr. T. B. Flower.* Seen there also by the late *Miss Powell,* of Henbury. As a casual upon refuse from a straw-paper mill at Henley, near Wells; *Miss Livett.*

VI. VII.

88. L. ruderale, *L.*

Alien; on quays about Bristol, and near the shore of the estuaries, rare.

G. Crew's Hole. Kingsweston. Rather plentiful at St. Philip's Marsh. On the quays at Cumberland Basin.

S. Clevedon. Rownham Ferry. V. VI.

(*L. sativum, L.*, is frequently found in the neighbourhood of gardens, and on rubbish heaps.)

89. L. latifolium, *L.*

Native.

S. Near the Axe, between Brean Down and Brean. *Mr. T. B. Flower.* VII. VIII.

CAPSELLA, *Vent.*

90. C. Bursa-pastoris, *DC.* *Shepherd's Purse.*

Native. An extremely common weed, found everywhere by roadsides and in waste places. III.—X.

SENEBIERA, *Pers.*

91. S. Coronopus, *Poiret.*

Native; on damp pasture and waste land; common. VI. IX.

92. S. didyma, *Pers.*

Probably introduced with ballast about Bristol. Now frequent.

G. Sea Mills, abundant. Westbury-on-Trym.

S. Burnham. Weston-super-Mare. VII. IX.

(*Isatis tinctoria, L.* "Formerly cultivated about Keynsham, S., where I have occasionally found it." *Mr. T. B. Flower* in Swete's Fl. Brist.)

CAKILE, *Gaert.*

93. C. maritima, *Scop.*

Native; on the sandy coast of the Channel, between Clevedon and Burnham; plentiful in some places. VI.—VIII.

CRAMBE, *L.*

94. C. maritima, *L.* *Sea-Kale.*

Native; on the coast, perhaps now extinct.

S. Burnham. *Mr. T. B. Flower.*

RAPHANUS, *L.*

95. R. Raphanistrum, *L.*

Colonist; in cornfields, &c.; frequent. Sometimes with lilac flowers. VI. VII.

"The repetition of a generic name with the addition of 'istrum' or 'astrum' applied to a species, indicates that it is a useless or contemptible member of that genus, or bears a false resemblance to the species which comprise it." *Syme's E. B.*

96. R. maritimus, *Sm.* *Sea Radish.*

Native; near the coast; very rare.

S. Portishead. *Rev. W. W. Spicer!* Sandy fields, near Brean. *Miss M. W. Mayow, Mr. T. B. Flower.*

VI.—VIII.

RESEDACEÆ.

RESEDA, *L.*

97. R. lutea, *L.*

Native, or Colonist. Scarce about Bristol.

G. Combe Hill. Henbury. Shirehampton.

S. Pill. Portbury. Sandford. Walton-in-Gordano.

VI.—VIII.

98. R. suffruticulosa, *L.*

Alien, or Colonist. Very rare.

S. Anchor-Head rocks, Weston-super-Mare! It was found some years ago at Wells, by *Miss Livett.*

VII.—VIII.

99. R. Luteola, *L.* *Dyer's Weed.* *Weld.*

Native; on the rubble about the limestone quarries at Bristol, and elsewhere. Locally common. VII.—VIII.

CISTACEÆ.

HELIANTHEMUM, *Gaert.*

100. H. vulgare, *Gaert.* *Common Rock-Rose.*

Native; on dry, rocky banks and hilly places, especially about Clifton, where a white-flowered variety has been observed. VII.—IX.

101. H. polifolium, *Pers.*

Native.

S. On Brean Down. There is but one other habitat in Britain. This great rarity continues to grow plentifully, chiefly on declivities facing the south-west, where there are plants of huge size, and apparently of great age.

VII.—VIII.

(*H. canum, Dun.* Reported in error from Penpole Point, G. The plant was *H. vulgare.*)

(*H. ledifolium, Willd.* "Brean Down, Somerset," *Hudson.* An error. It is generally supposed that *Hudson* mistook *H. polifolium* for it.)

VIOLACEÆ.

VIOLA, *L.*

102. V. palustris, *L. Marsh Violet.*

Native.

S. Recorded from "Mendip Marsh, near the Minories," from whence we have seen a specimen collected by *Miss M. W. Mayow.* "Bog near the 'Castle of Comfort,' Mendip," *Herb. Dr. H. O. Stephens.* IV.—VI.

103. V. odorata, *L. Sweet Violet.*

Native. Plentifully distributed throughout the district. The type *violacea* is very much less frequent in the vicinity of Bristol than the var. *alba.* This has been accounted for by supposing that the blue violets have nearly all been dug up and transplanted into gardens, or hawked for sale in the streets, a fate which yearly befalls thousands of our ferns and spring flowers, not merely in this district, but in the neighbourhood of all large towns. In this genus the ordinary spring flowers do not generally ripen seed; later in the season minute apetalous flowers, which never expand, and are self-fertilized, develope seed in abundance. The leaves do not attain their full development until the fruit ripens; thus specimens of this species and of *V. hirta* when in fruit present an appearance very different from that of others gathered when the spring flowers are expanded. Both states should be represented in the herbarium. III. IV.

104. V. hirta, *L. Hairy Violet.*

Native; on shady banks and in rocky woods, frequent.

G. Bitton. Clifton Down. Shirehampton.

S. Brockley Combe. Cheddar. Clevedon. Congresbury. Easton. Frequent about Failand and in Leigh Wood.

If the var. *β. calcarea, Bab.*, is nothing more than a small state of this plant, we have it in Leigh Wood, where in some stony spots very tiny specimens may be found. As in the last species the leaves continue growing after the flowers fade, sometimes attaining very large dimensions. III.—V.

105. V. sylvatica, *Fries.*

Native.

a. V. Reichenbachiana, Bor.

On shady banks and in woods; not common, but to be found in many places. Near Bristol, it may be gathered in the wood at Combe Glen, and in hollow lanes about Failand.

β. V. Riviniana, R.

A more robust plant, and much more plentiful than var. *a.* Very abundant about Bristol, and not confined to shady places. Makes a great show in open parts of Leigh Wood and at Cheddar. A dwarf form — *V. flavicornis, Forst.*—is met with frequently. It grows chiefly on downs and dry turfy places. IV. V.

106. V. canina, *L.*

Native; on heaths and sandy ground; rare.

G. Kingsweston.

S. Burnham sand-hills. Leigh Down.

We have not seen *β. V. lactea, Sm.*, which, however, should be found amid the heath and bog of the southern portion of the district. IV. V.

107. V. tricolor, *L.* *Heartsease, Pansy.*

Native, or colonist; on cultivated ground. The large-flowered type is very rare, and usually found singly, but *β. arvensis* is everywhere common. V.—IX.

DROSERACEÆ.

DROSERA, *L.* *Sundew.*

108. D. rotundifolia, *L.*

Native; only on the peaty moors in Somersetshire, from Wedmore to Wells. VII. VIII.

109. D. intermedia, *Hayne.*

Native; with the last species. VII. VIII.

110. D. anglica, *Huds.*

Native. The only specimens we have are in the Stephens Herbarium, from Wedmore, S. VII. VIII.

POLYGALACEÆ.

POLYGALA, *L.* *Milkwort.*

111. P. vulgaris, *L.*

Native; on dry banks, heaths, and commons; common. The most frequent form at Clifton is *P. oxyptera, R.*

β. P. depressa, Wend. is chiefly to be found on damp heaths and moors, as on Yate Common, G. VI.—VIII.

112. P. calcarea, *F. Sch.*

Native; on the Mendips, very rare.

Sandford Hill, S. *Mr. W. B. Waterfall, "fide Mr. T. R. A. Briggs."* V.

CARYOPHYLLACEÆ.

DIANTHUS, *L.*

(One plant of *D. Armeria, L.*, was seen on a wall at West Town, S., July 20, 1880.)

113. D. cæsius, *Sm.* *Cheddar Pink.*

Native; on the Cheddar Cliffs, still plentiful.

Mr. T. B. Flower says that many years ago there was a large patch of this pink on St. Vincent's Rocks, near the Observatory. No doubt it had been planted there, and we believe it has now disappeared. VI. VII.

SAPONARIA, *L.*

114. S. officinalis, *L.* *Soapwort.*

Native; on the bank of the Avon, near Hanham, G., now scarce. Abundant on a sand-bank between Brean and Burnham, S , and also on hedge-banks at Burnham. Wells, S., not seen since 1878, *Miss Livett.* With double flowers in the Somersetshire habitats, and, no doubt, introduced there. VIII.

SILENE, *L.*

115. S. anglica, *L.*

Native, or colonist. Recorded only from Yatton, S., and very scarce even there. VI.—X.

116. S. inflata, *Sm.* *Bladder Campion.*

Native; in fields and by waysides, rather common. The hairy variety *(S. puberula, Jord.)* is often met with; it differs but little from the type. VI.—VIII.

117. S. maritima, *With.* *Sea Bladder Campion.*

Native; on the Channel shore only, rather rare.

S. Clevedon. Weston-super-Mare. Brean Down.

VI.—VIII.

LYCHNIS, *L.*

118. L. Flos-cuculi, *L.* *Ragged Robin.*

Native; in ditches and swamps, frequent. Rarely with white flowers. V. VI.

119. L. vespertina, *Sibth.*

Colonist; in borders of grass-fields, and under hedges, generally distributed. VI.—IX.

120. L. diurna, *Sibth. Red Campion.*

Native; on banks and in moist, shady places, very common. Staminiferous plants are far more abundant than those bearing pistils. The variety with white flowers is rare, but some luxuriant plants of it have been observed in a damp wood bordering the lane between Leigh and Failand Farm, S. V. VI.

121. L. Githago, *Scop. Corn-Cockle.*

Colonist; on arable land, not common.

G. Shirehampton. Stapleton.

S. Failand. Nailsea. Yatton. VI.—VIII.

SAGINA, *L.*

122. S. procumbens, *L.*

Native: in waste places, by footpaths, and on turf: very common. V.—IX.

123. S. apetala, *L.*

Native; on walls and in dry places; very common. V.—IX.

124. S. ciliata, *Fr.*

Native. We have this species reported only from Stapleton and Clifton, G. There is little doubt, however, that it will be found in other localities when its distinctness from the last is better understood. V.—VI.

125. S. maritima, *Don.*

Native; only on the coast from Weston-super-Mare to Burnham; rather rare. V.—IX.

126. S. nodosa, *E. Meyer. Knotted Spurrey.*

Native; in sandy and peaty places, locally plentiful.

S. On the peat towards the southern limit of the district. Kewstoke Sands, Sands between Weston-super-Mare and Brean Down, and Burnham Sands. In the maritime localities the plant is very glandular-hairy, *(S. glandulosa, Bess.)*. VII. VIII.

HONKENEJA, *Ehrh.*

127. H. peploides, *Ehrh.*

Native; abundant on the sandy shore of the Bristol Channel, from Clevedon to Burnham, S. VI.—IX.

ALSINE, *Wahl.*

128. A. verna, *Jacq.*

Native; on the Mendip Hills, rare.

Mendip Hills below Banwell, abundant, 1846, *Mr. T. B. Flower.* Mendip Marsh, at the Minories, 1866! *Miss M. W. Mayow.* Specimens in the Stephens Herbarium are marked "near the 'Castle of Comfort,' Mendip Hills." V. IX.

(*A. tenuifolia, Wahl.* We cannot retain this plant in the Bristol Flora. There is little doubt that it was found at Clifton half a century ago, but the circumstances are unknown, and no specimens are extant. It is included in Mr. Rootsey's list of Bristol Plants, pub. 1828, with the habitat "Foot of St. Vincent's Rocks." "In the chink of a wall near Cornwallis Grove, Clifton, *Miss M. Atwood.*" *Swete, Fl.* 14.)

ARENARIA, *L.*

129. A. trinervis, *L.*

Native; in damp and shady places, common. V. VI.

130. A. serpyllifolia, *L.*

Native; on walls, banks, and in dry spots throughout the district. Very common. VI.—VIII.

STELLARIA, *L.*

131. S. media, *Vill. Chickweed.*

Native; a common weed in all kinds of situations, and very variable in habit and luxuriance.

δ. *S. umbrosa, Opitz. S. grandiflora, Woods.*

G. This well-marked variety is frequent about Charfield and Sodbury.

S. Bishport, Englishcombe, and Winscombe. III.—IX.

132. S. Holostea, *L.*

Native; everywhere on hedgebanks. IV.—VI.

133. S. glauca, *With.*

Native; only on the peat towards the southern limit of the district, rare. V. VII.

134. S. graminea, *L.*

Native; in dry, heathy, and bushy places, frequent.

G. Bank of Avon. Berkeley. Clifton Down. Mangotsfield. Glen Frome, near Stapleton. Westbury-on-Trym.

S. Leigh Wood. Yatton. Wells. V.—VIII.

135. S. uliginosa, *Murr.*

Native; in wet and swampy places, common. V. VI.

MALACHIUM, *Fries.*

136. M. aquaticum, *Fr.*

Native; on ditchbanks, rare. *Swete's* remark, "Common throughout the district," is inexplicable.

G. By the river Frome, near Stapleton.

S. Knowle, *Miss Livett.* St. Anne's Wood, Brislington. VII. VIII.

CERASTIUM, *L.*

137. C. glomeratum, *Thuil.*

Native; on banks, walls, and railway ballast. Common. IV.—IX.

138. C. triviale, *Link.*

Native; on wall-tops, banks, and in pasture land. More common than the last. IV.—IX.

139. C. semidecandrum, *L.*

Native; in dry places, rather rare.

G. St. Vincent's Rocks. Durdham Down. Stapleton. Brandon Hill.

S. Clevedon. Cheddar. IV. V.

140. C. pumilum, *Curt.*

Native; on rocks about Clifton, local. St. Vincent's Rocks. Clifton Down. Rocks near the Sea Wall. The Stephens Herbarium possesses a good series of specimens from St. Vincent's Rocks, and some interesting letters from Prof. Babington with reference to this plant. IV. V.

141. C. tetrandrum, *Curt.*

Native.

G. St. Vincent's Rocks, Durdham Down, and Brandon Hill, Bristol. Sea Mills. Dr. H. O. Stephens submitted a Clifton specimen to Prof. Babington, who pronounced it to be his *C. atrovirens*, "with shorter footstalks than usual."

S. Elevated rocks at Cheddar. V. VII.

MOENCHIA, *Ehrh.*

142. M. erecta, *Sm.*

Native. There are specimens in Dr. Stephens' Herbarium marked "Keynsham" and "Brandon Hill," no date. The authority is undoubted, otherwise we might hesitate to include this plant in our Flora, in the absence of additional records V. VI.

LEPIGONUM, *Fries.*

143. L. rubrum, *Fr.*

Native; in sandy and heathy places, rare. It grows in several spots on the common near Mangotsfield, G. VI.—IX.

144. L. marinum, *Wahl.*

Native. Abundant about the estuaries in muddy and marshy situations. VI.—IX.

It is probable that other forms of *Lepigonum* are to be found in the district, but at present our records are confined to the species mentioned.

SPERGULA, *L.*

145. S. arvensis, *L.*

Native; on cultivated land, rather rare.

G. Horfield. Stapleton.

S. Fields near the coast between Clevedon and Portishead. Yatton.

SCLERANTHUS, *L.*

146. S. annuus, *L.*

Native; on dry sandy ground, very rare.

G. It still lingers on Brandon Hill, half-a-dozen specimens having been seen this season (June 10, 1881). We wish that all the plants formerly stationed at this spot had been able to battle as successfully against the adverse environment.

S. On the railway near Yatton Station! *Mr. W. E. Green.*

MALVACEÆ.

MALVA, *L.*

147. M. moschata, *L.* *Musk Mallow.*

Native; in waste places and by roadsides, frequent.

G. Very plentiful about the railway between Clifton and Avonmouth, and at Stapleton.

S. Clevedon. Leigh. Milton. Yatton. VII. VIII.

148. M. sylvestris, *L.* *Common Mallow.*

Native; very common everywhere. VI.—IX.

149. M. rotundifolia, *L.* *Dwarf Mallow.*

Native; in dry waste places, frequent.

G. Plentiful on a pebbly beach between the New Passage and Avonmouth. Shirehampton. Stapleton.

S. Brislington. Clevedon. Easton. Knowle. Strode. Long Ashton. VI.—IX.

ALTHÆA, *L.*

150. A. officinalis, *L.* *Marsh Mallow.*

Native; in marsh ditches near tidal waters; very rare.

G. In ditches near the rifle-range at Avonmouth, now scarce.

S. Portishead. VIII. IX.

151. A. hirsuta, *L.*

Alien. Grows sparingly on Pur Down, G., where it was discovered a few years ago by *Mr. W. E. Green.* VI.

LAVATERA, *L.*

152. L. arborea, *L.*

Native, or denizen. Occurs generally as an escape from gardens, but is doubtfully wild at one or two stations on the coast.

S. Clevedon. St. Thomas's Head. Woodspring, at the mouth of the river Wick; perhaps now extinct. Weston-super-Mare. VII.—IX.

TILIACEÆ.

TILIA, *L.*

153. T. intermedia, *DC.* *Common Lime-tree.*

In plantations, parks, and hedgerows, with no claim to be indigenous in the district. VII.

154. T. parvifolia, *Ehrh.*

Native. Truly wild in Leigh Wood, S., where it is abundant. VIII.

HYPERICACEÆ.

HYPERICUM, *L.*

155. H. calycinum, *L.*

Alien. Naturalized in Leigh Wood, in the railway cutting at Bourton, and at Clevedon, S. VII.—IX.

156. H. Androsæmum, *L. Tutsan.*

Native; in woods, frequent.

G. Haw Wood, Henbury. Frome Glen, Stapleton.

S. King's Wood, Yatton. Leigh Wood. Clevedon. Portishead. Wookey. VII. VIII.

(*H. elatum, Ait.*, has escaped from cultivation at Max, S., and at Worle, S.)

(*H. hircinum, L.* With the last at Max, S., "unquestionably planted," *Mr. W. B. Waterfall.*)

157. H. tetrapterum, *Fr. H. quadrangulum, Sm.*

Native; banks of ditches and streams, common. VII.

158. H. perforatum, *L.*

Native; in woods and on dry banks, common. VII. VIII.

159. H. dubium, *Leers.*

Native; in moist places, very rare.

G. Stapleton.

S. Leigh Wood. Yatton. VII.

160. H. humifusum, *L.*

Native; in many woods, and on shady banks, rather common. VII.

161. H. hirsutum, *L.*

Native; in woods, frequent.

G. Very plentiful in woods about Berkeley.

S. Leigh Wood. Walton-in-Gordano. Wells. Yatton. VII. VIII.

162. H. montanum, *L.*

Native. In bushy places on limestone; local, but frequent about Bristol.

G. Conham. St. Vincent's Rocks, and in the Great Quarry, Clifton.

S. Failand. Leigh Wood. Walton-in-Gordano. Weston-super-Mare. VII. VIII.

163. H. pulchrum, *L.*

Native. The most common *Hypericum* in the district. VI. VII.

ACERACEÆ.

ACER, *L.*

164. A. campestre, *L.* *Maple.*

Native; at least in Leigh Wood, S., where are many trees of good size. Common in hedgerows. V. VI.

165. A. Pseudo-platanus, *L.* *Sycamore.*

Alien; in woods, hedges, and plantations, common. V. VI.

GERANIACEÆ.

GERANIUM, *L.*

166. G. phæum, *L.*

Alien; established in one or two spots, very rare.

G. Sea Mills, sparingly, from 1868 to the present time.

S. Stockwood, and on the banks of the stream at Long Ashton. *Swete, Fl.* 19. Probably extinct in both these habitats. V. VI.

(*G. striatum, L.* will be found as an escape from cultivation in many places, notably at Bourton Combe, S.)

167. G. pratense, *L.*

Native. This beautiful Geranium is frequent in moist

pastures, and especially by the sides of rivers, throughout the district. In the near vicinity of Bristol it is very scarce, as might be expected; the existence of so attractive a wild-flower being incompatible with the extension of a large city.

G. Bitton. Ashley Hill. Chipping Sodbury. Filton. Tortworth.

S. Ashton. Brockley. Draycot. Kewstoke. Keynsham. Pensford. Wells. VI.—VIII.

168. G. sanguineum, *L.*

Native; on dry limestone banks, very rare.

G. Plentiful about St. Vincent's Rocks, Clifton.

S. Walton-by-Clevedon. *Mr. W. E. Green.* VII.

169. G. pyrenaicum, *L.*

Alien, or denizen in this district. Very rare.

S. Plentiful in a cultivated field near Abbot's Leigh, 1878. Clevedon. Wells. In a churchyard at Wells. Hedgebanks at Englishcombe, May, 1881. VI. VII.

170. G. molle, *L.*

Native; in waste places and dry spots, very common. The variety with white flowers at Weston-super-Mare, 1880. IV.—VIII.

171. G. rotundifolium, *L.*

Native; on and under old walls and in hedgebanks, locally common.

G. Hanham. St. Vincent's Rocks. Sea Mills. Shirehampton. Stapleton.

S. Abundant under the walls of Ashton Park, by the road to Abbot's Leigh. Clevedon. Portbury. Yatton. By the Kennet and Avon Canal, near Combe Hay. VI. VII.

172. G. pusillum, *L.*

Native; on gravelly soil. Very rare, or, perhaps, sometimes overlooked.

G. Combe Hill. Crew's Hole. Shirehampton.

S. Bedminster. VI.—VIII.

173. G. dissectum, *L.*

Native; in pastures and waste places. Very common. VI.—VIII.

174. G. columbinum, *L.*

Native; in thickets and dry pastures, and on banks, frequent.

G. St. Vincent's Rocks, and bank of Avon. Stapleton.

S. Plentiful at Cheddar, where on the dry turfy slopes may be seen minute specimens of great beauty, bearing but one flower on the summit of a tiny stem. Clevedon. Wells. Weston-super-Mare. Yatton. VI. VII.

175. G. lucidum, *L.*

Native. Singularly common about Bristol, considering how very seldom it is met with in some districts. Grows chiefly on walls and in rocky places. Common also at Bath, Wells, Weston-super-Mare, and Yatton, S. V. VIII.

176. G. robertianum, *L. Herb-Robert.*

Native; on hedgebanks, and in waste shady places, very common.

The variety with white flowers at Claverham, S. *Miss Winter.* V.—VIII.

ERODIUM, *L'Hérit.*

177. E. cicutarium, *Sm.*

Native; in dry places, common. Varies very greatly in size and appearance; large coast specimens are sometimes mistaken for the next species. VI. VIII.

178. E. moschatum, *Sm.*

Native; only near tidal waters, very rare.

G. Bank of Avon. Penpole Point.

S. Weston-super-Mare. VI. VII.

179. E. maritimum, *Sm.*

Native; on elevated pastures, local.

G. Penpole Point, perhaps now extinct.

S. Roman entrenchment in Leigh Wood; small plants amongst the turf. Court Hill near Clevedon. Very luxuriant on the hills about Goblin Combe. Dolbery Camp, and frequent on other eminences in that neighbourhood. VI.—IX.

OXALIDACEÆ.

OXALIS, *L.*

180. O. Acetosella, *L.* *Wood Sorrel.*

Native; in woods and moist shady places, frequent. The flowers are rarely pink or purplish.

G. Abundant by the river Trym below Westbury.

S. Cheddar. Failand. Leigh Wood. Wells. Yatton. V.

LINACEÆ.

LINUM, *L.*

181. L. angustifolium, *Huds.*

At present reported only from Wookey, S., by *Miss Livett,* but is likely to be found elsewhere. VII.

182. L. usitatissimum, *L.* *Common Flax.*

Alien. Is met with in many spots, but scarce about Bristol, and perhaps not permanent anywhere. VII.

183. L. catharticum, *L.*

Native. Very common on dry turfy banks and elevated pastures. VI.—VIII.

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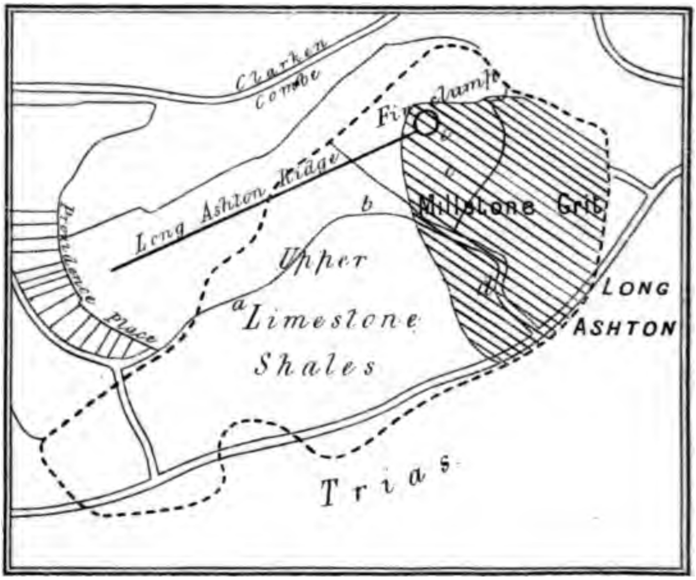


Map of the Millstone Grit near Long Ashton.

Scale 6 Inches to 1 Mile.

On the Mapping of the Millstone Grit, at Long Ashton, near Bristol.

By Prof. C. Lloyd Morgan, F.G.S., Assoc. R.S.M.

THE object of this note is to correct an error in the mapping of the Millstone Grit on the hill above the village of Long Ashton.

The dotted line on the accompanying map shows Mr. Sanders' boundary of the Grit, followed by the Geological Survey. The area diagonally shaded shows the limits of the Millstone Grit according to my own observations.*

That which Mr. Sanders took to be the northern and eastern boundary of the Grit I hold to be a band of reddish Sandstone in the Upper Limestone Shales, which crops up somewhat boldly at the surface. The beds which immediately overlie it have been recently rendered visible in a section exposed during the formation of a cricket-field by Mr. Kemp, the Head Master of Long Ashton School. The section is in parts confused,

* I first visited Long Ashton Ridge with my friend, Mr. James Dallas, F.L.S., then Curator of the Bristol Museum, and had, for awhile, the advantage of his advice and assistance. Since his appointment to the Curatorship of the Exeter Museum, I have been forced to continue the observations alone. And for the conclusions reached I am alone responsible.

owing to its superficial nature. The following is, however, my reading of it:—

	FEET.
Brownish sandy beds	6
White close Sandstone	1
Yellow and brownish-red sandy Marl, with white-Clay-Marl bands	8
Purple Marl	4
Hard Limestone	6½
Friable yellow-red Sandstone	4½
Close-grained hard Sandstone	2½
Purple Clay Marl	24
Limestone, massive, and highly ferruginous in parts ...	18
Silicious Shale with black ferruginous bands... ...	6½
Solid Limestone	8
	89

The position of this cricket-field section is marked *a* on the map. The beds clearly belong not to the Millstone Grit but to the Upper Limestone Shales.

At the point marked *b* are several old quarries in which a hard purple limestone has been worked. I take it that these limestone beds, which I estimate at 20 or 25 feet in thickness, overlie somewhat closely the top beds of the cricket-field section, and there are indications of a sandstone bed in turn overlying them.

At the point marked *c* on the map Millstone Grit has been largely quarried. The beds dip at an angle of 23½°.

From the lowest grit exposed, the sandstone bed which marks Mr. Sanders' boundary is distant about 125 paces in a horizontal line at right angles to the strike of the beds. This would give a thickness of say 143 feet, of which, as we have seen, 89 feet

are displayed in the cricket-field section at *a*, and say 21 feet at *b*; this leaves 33 feet in which the Upper Limestone Shales may shade into the overlying Millstone Grit.

At the point marked *d* in the map grit is exposed in the banks of the lane.

In considering the map it must be remembered that the firm line marks the axis of the ridge, from which the ground dips somewhat steeply in all directions. The marked south-west expansion of the area of the Upper Limestone Shales under consideration (*i. e.*, between the dotted line of the sandstone band and the area of the Millstone Grit) is due to the fact that the beds here are dipping with the hill.

Note on the Total Eclipse of the Moon,

4 OCTOBER, 1884.

By GEORGE F. BURDER, M.D.

A TOTAL eclipse of the moon, although less attractive to astronomers than a total eclipse of the sun, is not without features of interest, and the recent eclipse was rendered especially remarkable by the occurrence of a circumstance, which, although noted by old observers, had perhaps not been previously witnessed by any one now living. I refer to the almost total extinction of our satellite as an object visible to the naked eye.

As a rule, under favourable circumstances of weather and altitude, the moon remains a striking object in the sky even in the middle of total eclipse, appearing of a dull red or coppery hue. Thus, to cite two examples only, I find recorded in my notes of the total eclipse of 27 February, 1877, that "throughout the total phase the moon was quite a conspicuous object, shining with a dull red light"; and, again, of the total eclipse of 23 August in the same year, I wrote that "the moon, even in the middle of the total phase, was a conspicuous object in the sky, and the ruddy colour was well marked."

In the late eclipse the weather and other circumstances were singularly favourable for observation; yet for some time before and after the middle of totality nothing was visible of the moon beyond a faint dingy-brown nebulous spot, to which it was impossible to assign any definite form or dimensions. From the window of a room in which lights were burning it could not be

seen at all, and in the open air many persons failed to discover it. With an opera glass the nebulous spot was resolved into a well-defined disc of the proper form and dimensions, but still very faint and dingy.

That this unusual obscurity of the moon is not to be explained by the central character of the eclipse and consequent deep immersion of the moon in the earth's shadow, will clearly appear when it is stated that in the eclipse of August, 1877, above referred to, the immersion of the moon in the earth's shadow was still deeper than on the late occasion; and, further, that in the recent eclipse the unusual obscurity of the eclipsed portion was such as to attract notice even before the immersion was complete—indeed it was not until within a few minutes of totality that the dark part of the moon could be distinguished with the naked eye.

A consideration of the causes of these great differences in the visibility of the eclipsed moon raises of necessity the previous question of the reason why the eclipsed moon is visible at all; and it is chiefly because there appear to me to be reasons for doubting the correctness of the views commonly accepted on this matter that this note is offered.

The following quotation from a newspaper article published in anticipation of the late eclipse may be taken as representing the current opinion:—

"Even after the immersion in the shadow some of the rays of the sun's light are reflected through our atmosphere on the lunar surface, just as we receive the rays after the sun has really descended below our horizon. . . . . The explanation of the visibility or the partial or total disappearance was first satisfactorily given by Kepler, who showed that if the part of the terrestrial atmosphere through which the solar rays pass be tolerably free from vapour, the red rays are almost entirely absorbed, leaving the blue rays, which give too feeble an illumination to render the moon

visible; while, on the other hand, if the atmosphere be highly saturated, the blue rays are more effectually absorbed, and the red rays transmitted to the moon, thus rendering it visible. The parts of the atmosphere through which the rays pass are sometimes saturated to different extents; hence some parts of the disc are seen better illuminated than others."

To take the last part of this quotation first, it may be well to explain that the main differences in the illumination of the different parts of the eclipsed moon are undoubtedly due to the position of the moon in the earth's shadow. The portions of the moon's disc nearest the edge of the shadow are the brightest, those most deeply immersed are the darkest. Hence in the first part of the total phase the preceding or eastern portion of the disc is the darker, the following or western portion is the brighter; while in the latter part of the total phase the reverse obtains. In the middle of the total phase, if the moon pass above the centre of the shadow, the upper portion will be the brighter; if it pass below the centre, the lower portion will be the brighter. If the eclipse be nearly central, then in the middle of totality the central parts of the moon's disc will be somewhat darker than the surrounding parts. These are the appearances which should on theory be observed if the source of illumination is tolerably uniform around the earth's circumference, and according to my own observations they are the appearances which are actually observed with little or no variation. The intrinsic differences in the brightness of the different parts of the moon's surface—differences familiar to everybody—must of course be also taken into account. I doubt if there is sufficient evidence of inequalities of illumination of the different parts of the moon's disc beyond what may be referred to one or other of these explanations.

Passing to the more essential part of the theory stated in

the foregoing extract, its inadequacy may, I think, be shown by the following considerations.

The portion of the earth's atmosphere through which the solar rays will pass to reach the moon will clearly be an entire ring, embracing almost all varieties of terrestrial climate. It is inconceivable that there should be anything approaching to uniformity in the hygrometric condition of this atmospheric ring. It is almost equally inconceivable that there should be any very large diversity in the *average* hygrometric condition of the whole ring at any two epochs. But in order to account for the observed results, both of these improbable hypotheses must be assumed. For, in the first place, if there were not an approach to uniformity throughout the ring on any given occasion, the variations due to the position of the moon in the shadow (as explained above) would be in a great measure masked, which, as a rule, they certainly are not; and, in the second place, if there were not a very large diversity in the *average* condition of the whole ring at two epochs, there would be no explanation of the phenomenon now under discussion. It cannot be that the large hygrometric differences which we know to exist between the tropical and the arctic regions should have an effect scarcely if at all appreciable, and that the small differences which are all that we can imagine possible between the average condition of the whole atmospheric ring at one time, and its average condition at another time, should suffice to explain the difference between conspicuous visibility at one time and absolute disappearance at another time.

The suggestion of the *solar corona* as the source of the light which illuminates the eclipsed moon seems so obvious that I cannot suppose that it has not occurred to others besides myself. But, so far as I know, it has not hitherto been published, and certainly it has not been generally accepted. To my mind it fulfils all the conditions required. Whatever the

real nature of the corona may be, no doubt remains of its existence as an actual luminous body surrounding the sun. From the degree to which its light mitigates the darkness on the earth in a total eclipse of the sun, we may form an estimate of the degree to which it will illuminate the moon in that which is to the moon a total eclipse of the sun. It is true the illumination will not be equal in the two cases, because the earth, being very much larger than the moon, will intercept to the moon a very much larger portion of the corona than the moon can intercept to us, and the portion so intercepted will include all the more central and brighter parts; still, even so, enough may remain, and it must be remembered that the fainter parts of the corona probably extend very far beyond what has been actually seen. Whether the amount of light given out by the corona varies greatly at different times, may not be easy to prove, but at least it may be said that the inconstancy of form and general appearance which the corona has exhibited in different eclipses, renders such variation probable. This being admitted, we have only further to assume that in the rare instances in which the eclipsed moon becomes invisible, the light of the solar corona is at its minimum, and the explanation is complete. Possibly, in course of time, with improved methods of investigation, this coincidence of the two phenomena, at present a speculation, may become an observed fact.

Sub-aerial Denudation and the Avon Gorge.

By Prof. C. LLOYD MORGAN, F.G.S., Assoc. R.S.M.

CONTENTS.

1.—*Introduction.*

WHEN the Geological Section of this Society did me the honour of inviting me to be their president, I bethought me in what way I could best fulfil what seemed to me one of the most important duties of that position. For it is, I take it, the primary function of such a Society as ours, to investigate and elucidate the Natural History—using these words in their widest signification—of our own immediate neighbourhood. And it should therefore be the object of the president of the Geological Section, to endeavour to add something to our

knowledge of the geology of our district, and to indicate to his brethren of the hammer what seem to be the most promising fields of research.

Now there is one branch of Geology that has always had for me a special charm, probably through the influence of my esteemed master, Sir A. C. Ramsay, and that is the dependence of scenery on geological structure. And it so happens that this point is admirably exemplified in many parts of our own district. It seemed to me therefore, that it would be worth while trying to work out this subject in some detail for the country in the neighbourhood of Bristol. For I felt that assuredly there is nothing like such detailed examination for proving or disproving the truth of those principles of Denudation which are now so generally accepted among geologists. Such work would moreover afford opportunities of verifying that most admirable map which Mr. Wm. Sanders has bequeathed to us—a piece of work of which Bristol may well be proud. The task I set myself, then, was the investigation, in some detail, of the influence of geological structure on the scenery of the Avon basin, and at the same time the verification of the recognized geological map of the district. But the subject is a large one, and I hereby call upon the members of the Bristol Naturalists' Society in general, and upon those of the Geological Section in particular, to co-operate with me in this work.

In this paper I propose to deal with the Sub-aerial Denudation of that section of the Avon Basin which lies between Bristol and the Channel. But first I must say somewhat by way of introduction.

The errors of geologists of the past are apt to live on in the popular notions of to-day. Two such cardinal errors there are in connection with my present subject. They may be termed the Diluvial error and the Volcanic error. Looking out on the diversified surface of the land, and impressed with the

grandeur of its physical features, men, so soon as they began to admit the possibility of such features being caused at all, searched throughout nature for causes sufficiently potent to produce the high ridges, the broad valleys, and the deep ravines which they saw around them. One cause alone seemed of sufficient power to raise the land into ridges many miles in length and a thousand feet or more in height. And that cause was fire (so-called), with whose work they were well acquainted in volcanic outbursts of great magnitude. It seemed, moreover, to be obvious that the same volcanic force which upheaved the hilly ridge would also tear through its midst huge rents and chasms. Speaking, for example, of the Mendips, Dean Buckland said in 1849, in his presidential address at the first annual meeting of the Somersetshire Archæological Society, "If we ask the cause of the extensive elevation of a chain of hills, 20 miles long, and from 3 to 6 miles wide, and from 200 to more than 800 feet in height, we must refer it to the same uplifting and explosive force of vapours generated within the earth by the subterraneous fires, which are still producing earthquakes and exploding ashes and streams of lava in regions which are at this time agitated by nearly 200 burning volcanoes on the actual surface of the globe. Fractures and dislocations which attended the elevation of these strata from the bottom of the sea may be seen in the rocks at Cheddar Cliffs, on the east flank of Mendip; and in the yawning chasms of Brockley Combe and Goblin Combe, on the west side of Broadfield Down, near Bristol; and in the gorge through which the Avon passes at Clifton." (*Proceedings*, 1849-50, p. 17.)

Thus did Dean Buckland, who may be taken as the representative of a bygone age of Geology, account for the upheaval of such ridges as we find in our neighbourhood, and at the same time for such deep ravines as the Clifton Gorge. And how did the Dean account for those wider and more open valleys, in the

formation of which volcanic force would seemed to have played no part? Here, again, there would seem to be but one agent of power sufficiently magnificent to produce these physical features—the mighty ocean. Such a valley, writes the Dean (*Trans. Geol. Soc.*, ser. ii., vol. 1, p. 96), "must be referred exclusively to the removal of the substance that once filled it; and the cause of that removal appears to have been a violent and transient inundation. . . . The diluvian waters to which these effects must be referred (if we except the very limited and partial action of modern causes, such as of torrents in cutting ravines, of rivers in forming deltas, of the sea in eroding its cliffs, and of volcanoes in ejecting and accumulating their exuviæ) appear to have been the last agents that have operated in any extensive degree to change the form of the earth's surface."

Vulcan and Neptune, then, shared the honour of preparing for us the scenic beauty of the earth's surface. Opinions differed as to the question to which deity we were most indebted for the production of our scenery. But no doubt the majority sided with old Buffon, who thus concludes the first book of his Natural History: — "From all these observations we may fairly conclude," he says, "that it is the continual motion of the flux and reflux of the sea which has produced mountains, valleys, and other inequalities on the surface of the earth; that it is the currents of the ocean which have hollowed valleys, raised hills, and given them corresponding directions; that it is those waters of the sea which by transporting earth, &c., and depositing them in horizontal layers, have formed the parallel strata; that it is the waters from heaven which by degrees destroy the effects of the sea, by continually lowering the summits of mountains, filling up valleys, and stopping the mouths of gulfs and rivers, and which, by bringing all to a level, will, in the course of time, return this earth to the sea, which, by its

natural operations, will again form new continents, containing valleys and mountains exactly similar to those which we at present inhabit." (*Barr's Translation*, vol. i., pp. 67, 68.) For such heresies as these was Buffon invited by the Sorbonne to publish a formal recantation, wherein he said, "I abandon everything in my book respecting the formation of the earth." And modern Geology is for once in accord with the Church in deeming heretical such views as these, curious inversions as they are of modern geological doctrine.

For as determinants of the scenery of such a district as ours, neither Vulcanism nor Neptunism can supply a *vera causa*. Among geologists the Volcanic error and the Diluvial error are well-nigh things of the past. They are forced to shun the light and lurk in that shadowy land that is tenanted by popular notions. The geologist of to-day believes that such ridges as border or intersect the Avon Basin are the result, not of "the uplifting and explosive force of vapours, generated within the earth by subterranean fires," but of intense lateral pressure, by which the strata were thrown into folds, just as a number of pieces of cloth, placed one upon another, will be thrown into folds if pressed from side to side. In proof of which he points to the fact that if you, in imagination, straighten out the strata folds, they will occupy a longer arc of the earth's surface than they do now after the lateral compression. The rocks are not blown out as a bubble, and so put on a stretch, they are compressed into a shorter space; just as are the layers of cloth when they are pressed from side to side. And this lateral pressure, which would seem to be definitely connected with the secular cooling of the earth, has acted, in our district, in the main in a N. and S. direction, and has thrown the strata into folds having a general E. and W. trend.

But the ridges that we see are but small fragments of the bold curves which were produced by this intense lateral pressure

of a long-ago age—a pressure that would seem to have set in in post-Carboniferous, pre-Permian times. By lateral pressure, indeed, were the strata *raised*, but by sub-aerial denudation they have been *carved*. The deep ravines and the broad valleys are alike the work of processes of earth-sculpture, effected in the main by rain and rivers. The vast amount of detritus carried down to the sea by rivers—detritus which has contributed largely to the formation of the sand and mud-banks of the Severn estuary—is the waste matter removed during the process of sculpture, and adds not a little to the weight of other evidence in favour of the hypothesis of sub-aerial denudation. In a word, just as Fire and Diluvium were the watchwords of the physical geologists of a past generation, so is Denudation the watchword of the physical geologist of to-day.

2.—*Sub-aerial Denudation, general and special.*

The agents of sub-aerial denudation may conveniently be divided into two classes; first, those which exert their influence over the general surface of the country, such as rain, frost, and that more extended action which is known as weathering; secondly, those which exert their influence along special lines or over special areas, such as rivers and streams and glaciers. We may call the work done by the first class of agents, *general denudation*, and that done by the second class of agents, *special denudation*. And we may say that the vertical contouring of the country—with which alone we are here dealing—is due to the *differential action of general and special denudation on rocks of different powers of resistance.*

The action of general denudation may be likened to the action of sandpaper; that of special denudation to the action of a file. If we take one of those not uncommon slabs of slate rock, through the midst of which there runs a band of much harder quartzite, and, choosing a flat surface, apply our file to

this, keeping its cutting edge parallel to the surface, we shall cut a deep notch-like groove in the slab. The groove will be of equal depth in the soft slate and in the hard quartzite; for the depth to which the file can cut into the mass as a whole, is limited by the depth to which it can cut into the hardest band. Now, laying aside our file, let us apply our sandpaper. After scouring vigorously for a short time, we shall find that, in the softer slate, the material has been worn away on either side of the groove to such an extent that the groove has become a wide depression, with sides very gently sloping down to that which was the bottom of the notch-like groove. But in the quartzite band the case is different. Here the sandpaper has less effect. The groove is scarcely or not at all widened. The quartzite band, moreover, stands out as a ridge across our slate; for the sandpaper has worn away the softer slate on either side of the harder band.

Now let us see how far this illustration serves to aid us in the comprehension of the action of general and special denudation on a large scale. The action of a river is like the action of our file; it cuts a deep notch, gorge, or ravine. It is true that the river-file has some *lateral* play; for streams not only cut downwards but also eat into their banks and thus cut sideways. And they do this the more the softer the strata through which they flow. Still this only somewhat widens the groove. And it remains true that the office of rivers is to cut deep trenches into the surface of the land. They are the agents of denudation along special lines. And just as the file is unable to cut deeper into the softer slate than into the harder quartzite, so is a river unable to cut deeper into softer than into harder rocks—that is, so long as the softer rocks lie further up stream than the harder rocks. A band of hard rock, in fact, limits the depth to which a river can cut its way down into all the strata which lie further up stream, no matter how soft they may be.

The action of rain, frost, and the weather, on the other hand, is like the action of the sandpaper in our experimental illustration. The action is general over the entire surface; not special along definite lines. It wastes away the surface over the area of the softer strata ; but having less effect on rocks of greater resisting power, leaves them to stand out as bold ridges. Its action, moreover, is not limited in any way by the depth to which it can waste the harder bands. That which limits the depth of its action is the level of the river into which the detritus, which results from the general waste, is carried. For unless the detritus be removed, further waste is impossible. And thus we come to see that a band of hard rock, in limiting the depth to which a river can cut its way down into the rocks which lie further up stream, determines at the same time the level to which general denudation can reduce the whole surface of the land which lies up stream.

3.—*The Physical Features of the Area under consideration.*

The physical features of the area under consideration *(see map)* are in some respects remarkable. The Avon which has, above Bristol, emerged from a woody gorge, passes, near Bristol, through more open country, extending right and left from either bank, and then, below Bristol, makes its way between the steep slopes, and, in places, precipitous rock faces of the Clifton Gorge, emerging thence into more open country ere it finally passes through a band of Severn flats into the Bristol Channel. Opening out into the main ravine are several lateral valleys or gullies, some of them having now dry beds, others occupied by brooks or " pills."

A bird's-eye view of this part of the country will show on the Somersetshire side of the Avon a well-marked ridge of Downs, trending to the S.W. On the Gloucestershire side the ridge is split into two portions, of which one soon ends off, as

the tongue-shaped Clifton Down, while the other, somewhat further north, passes N.E. as Durdham Down, and then making a bold curve round Westbury, passes W. and a little S., along Henbury Down and King's Weston Down, to end off at Penpole Point. Between Henbury Down and King's Weston Down the ridge is deeply notched at Coomb Dingle, and through the notch runs the Henbury branch of the Trym. Within this horse-shoe ridge of Downs lies the lower, but never very low, land, through which the Trym makes its way to the Avon.

On the Somersetshire side of the Avon there runs, at the foot of the more southerly slope of the Downs, a broken and discontinuous ridge, marked by tumps and wooded clumps, and continued, on the Gloucestershire side, by Brandon Hill and the ridge on which the University College stands. North of the ridge of Downs, on the other hand, runs a line of depression, the collecting ground of several streamlets, tributaries of the Avon. North of this, again, is a well-marked ridge curving round from Failands House through Abbot's Leigh; through this ridge the tributary streams cut deep notches. North of this once more is another somewhat discontinuous line of depression, where the tributary streams themselves receive minor tributaries. Finally, to the north of this is irregularly rising ground, through which the tributaries cut notch-like valleys to the Avon.

Such, in brief, are the physical features of the area. Let us now see how far this physical configuration is dependent upon geological structure.

4.—*The Geological Structure of the area under consideration.*

The rocks in our area may be divided into two series, an older and a newer; whereof the newer lie more or less horizontally on the upturned edges of the older, and occupy the depressions which resulted from a very ancient denudation.

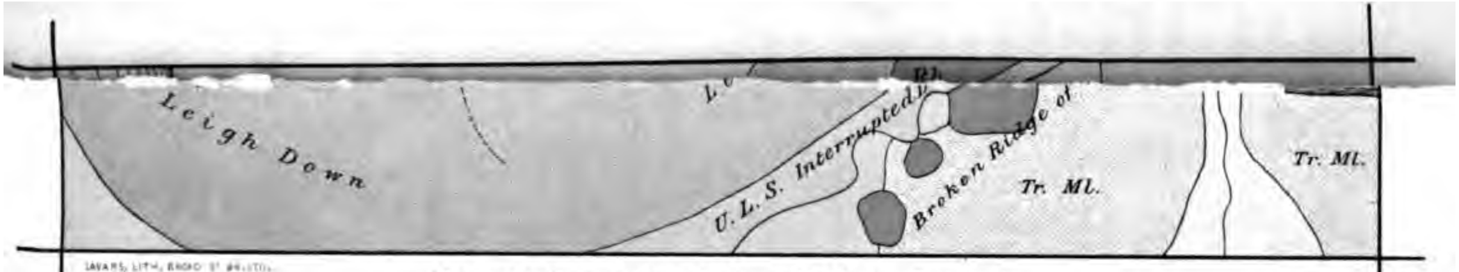
To begin with the older series. The broken ridge, of which

Brandon Hill forms a part, is composed of hard Millstone Grit, dipping to the S.E. at an angle of some 25°. That is followed by the softer Upper Limestone Shales, which form the southern slope of the Downs, and give rise to hollows or depressions, generally filled up with the rocks of the newer series. The whole ridge of the Downs, from Leigh Down, through Durdham Down, Westbury Down, Henbury Down, King's Weston Down, to Penpole Point, is formed of massive Mountain Limestone. How it comes that Clifton Down is separated from Durdham Down, we shall see presently. The depression to the N. of Leigh Down is occupied by softer Lower Limestone Shales. The Failands ridge, to the N. of this depression is composed of the upper and harder conglomeratic beds of the Old Red Sandstone. And the discontinuous depression yet further N. is occupied by the lower and softer beds of the same group of Old Red rocks: the discontinuity being partly due to overlying newer beds. The same soft Old Red rocks also occupy the depression just W. of Stoke Bishop, on the Gloucester side of the Avon *(see map)*.

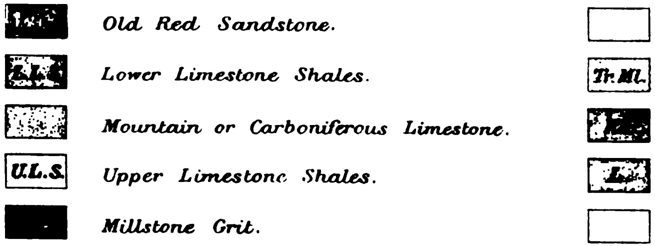
On the inner side of what may be termed the Westbury horseshoe, the Lower Limestone Shales form a discontinuous band —the discontinuity being due to the presence of overlying strata of more recent age. Beneath these beds the Lower Limestone Shales are without doubt continuous. Inside this band, again, is the band of harder Old Red Sandstone, which, E. of Shirehampton, N.E. of Cook's Folly, and again at Coomb House, rises out of the mantle of newer rocks which elsewhere hides it from our view. The lower and softer beds of the Old Red Sandstone probably occupy the rest of the area within the horseshoe. But they are almost entirely covered up by the newer secondary rocks.

The central axis of the horseshoe forms an anticlinal axis, from which the King's Weston and Henbury beds dip down

PLATE II.



MAP OF THE AVON BASIN N.W. OF BRISTOL.



SCALE. 1·5 INCH TO 1 MILE.

towards the N.W., while the Clifton and Durdham rocks dip down towards the S.E. There is, however, a roll in the strata which gives rise to a minor anticlinal, the axis of which is parallel to the Henbury Down, and runs a little to the N. of Coomb House, causing the beds of Old Red and Lower Limestone Shales, which are exposed near the junction of the Henbury and Westbury Trym, to dip to the S.E. Were the Mountain Limestone beds, the Lower Limestone Shales, and the upper Old Red beds, in each case, continuous over the main anticlinal, they would form a dome-shaped arch over the whole of the Westbury horseshoe. The upper part of the dome has, however, been entirely removed by denudation, so that only the spring of the arch has been left on either side.

Turning now from the Palæozoic rocks to the newer or Mesozoic beds which lie on their upturned edges, it will be sufficient for my present purpose to notice, first, the so-called Dolomitic Conglomerate, which immediately covers the older rocks over the greater part of the area where the Mesozoic beds occur. This Dolomitic Conglomerate is composed of larger or smaller fragments of the Palæozoic rocks, cemented together by a reddish or yellowish paste. The whole forms a mass of considerable hardness and resisting power. On its surface rests the newer red Keuper Marls; and here and there, above this again, we find the Rhœtic beds, and the yet more recent Lias.

The Dolomitic Conglomerate occupies the dip between the Clifton and the Durdham Downs, and may be seen in the New Road, near Proctor's fountain, resting upon the upturned edges of the Mountain Limestone. It occupies the greater part of the area enclosed within the Westbury horseshoe, and is found again fringing the northern side of the Henbury and King's Weston Downs. It forms on the Somersetshire side of the Avon the rising ground that lies to the north of the softer Old Red

depression, and is found in patches on the southern flanks of the Leigh Down limestone ridge.

Overlying the Dolomitic Conglomerate in larger or smaller patches are the Keuper Marls, as at Pill and to the S.W. of Westbury; and they form the low-lying band from Easton-in-Gordano through Shirehampton, King's Weston, and Lawrence Weston. This band dips gently down beneath the yet more low-lying fringe of Severn flats.

Overlying this again, N. of Blaize Castle, is a small patch of Rhœtic; while the Lower Lias Clay rests directly on Mountain Limestone in the area to the E. of Westbury.

A comparison of this section with the last, and a reference to the map, will show how clearly the general physical features of the area are determined by the general geological structure. So that the geological colouring in our map at once indicates the nature of the physical contours; while, *vice versa*, contouring would at once indicate geological structure.

5.—*The Age of the Rocks at King's Weston.*

In the map I have in the main followed Mr. Sanders and the Geological Survey. There are, however, one or two points in which I have made some slight alterations; and of some of these I would now say a few words.

In the first place, I have given a separate colouring to the Upper Limestone Shales, chiefly because the effects of the Clifton Fault thereby become more obvious. The line of division between these beds and the Mountain Limestone is, however, approximate.

Secondly, I have introduced a slight alteration where the Westbury Trym, after passing through the notch in the Mountain Limestone, passes out into the Dolomitic Conglomerate. Both Mr. Sanders and the Survey, map the Mountain Limestone in contact with Old Red at this point,

without any intervening Lower Limestone Shales. Such a state of things is impossible without a fault. And I can find no evidence of a fault or of this contact of Mountain Limestone and Old Red. I have therefore in the map substituted my own interpretation of the facts at this spot.

Thirdly, I have suggested a somewhat important alteration in the neighbourhood of King's Weston. There are two little patches of rock there, one of which is marked in Sanders' map, and by the Survey, as Old Red Sandstone, and the other as Mountain Limestone. With regard to the latter, there can be no doubt that of whatever age it may be it is not limestone. It is sandstone of some kind. With regard to the former, if it be Old Red Sandstone it is in a very puzzling position. If there be no fault, and none is marked on the Survey map, we must suppose that the Old Red Sandstone of the limestone ridge dips down under the ridge and then emerges on its N. side at King's Weston. This, though possible, is not, I think, even in a slight degree probable. For if we look at the Survey, section No. 14, or the section given in fig. 4 of De la Beche's Memoir, which passes through Blaize Castle, we shall see that the ridge of limestone is there regarded, and I am sure rightly regarded, as an anticlinal; and it is difficult to believe that this steep anticlinal is converted into a deep synclinal at a distance of a mile or less. I have found evidences of what seem to me to be the Upper Limestone Shales in the Blaize Castle woods, and at Lawrence Weston. And I think myself that it is very probable that the King's Weston beds will prove to be Millstone Grit, or those red sandy beds which occur in the Upper Limestone Shales near their junction with the Millstone Grit. The absence of conglomeratic bands and of friable red sandstone seems to distinguish these beds from those of the Old Red series. At the same time the beds are in places micaceous, a character which marks the Old Red. I have not yet worked

out the point quite to my satisfaction, nor in the absence of organic remains is it easy to come to a decided conclusion. I have therefore placed a ? on these patches of rock. And I bring this subject in this immature state before the Society, partly because, coming as it does within the area of my map, I could hardly pass it over without mention, and partly because it is one that seems to be worthy of the attention of the Members of the Geological Section. For if my views should prove to be correct, then coal under the Severn flats is a possible and not uninteresting corollary.

6.—*The Avon Gorge.*

"The vulgar notion respecting the Avon and its Gorge," writes Sir Andrew Ramsay, "is, that before the ravine was formed all the low ground through which the river and its tributaries flow was a large lake, that 'a convulsion of nature' suddenly rent the rocks asunder and formed the gorge through which the river afterwards flowed, and so drained the hypothetical lake."

This vulgar notion received its death blow when Professor Jukes, in 1867, showed "that the hypothesis of atmospheric erosion is applicable to the Clifton Gorge as to all similar places." This is now part of the common stock of geological knowledge. But I feel bound to draw attention to it here, partly to give unity to my subject, and partly because the truth of these views is enforced by the considerations which are to follow. I shall, however, content myself with a short quotation from Prof. Jukes; and a very few additional words of my own.

"Let the observer then," I quote from the *Geol. Mag.* of Oct., 1867, "stand on the highest point of Clifton Down and look up to the superior height of Dundry Hill, some six miles to the S., and he will see at once that the extension of the old oolitic sheet (of which the summit of Dundry is but an isolated

outlier) would pass some 2 or 3 hundred feet over his head. That the Lias itself rested directly on the Palæozoic rocks is shown by the fact of sheets of it still stretching across the Carboniferous Limestone to the N.E. of Durdham Down, still resting in patches on the Backwell hills to the W. of Dundry, and on that of the Mendips in the neighbourhood of Harptree.

"The Lias then formerly reposed on the Carboniferous Limestone of Clifton Down, and the Oolite spread over that. The Severn and its tributaries flowing over this Oolitic plain of course cut channels in it. The original form of the surface was such as to turn the Avon towards the Severn instead of towards the Thames. The course it originally took it has ever since maintained, cutting down through the horizontal Mesozoic cover, and through the Palæozoic rock it found underneath, in whatever position it might lie, or whatever materials it might be composed of."

We have here, in fact, a conspicuous example of the differential action of general and special denudation. The Limestone ridge of the Downs is like the Quartzite band in our experimental illustration. It has effectually resisted that wasting action which has removed the Mesozoic cover. The Clifton Gorge is no chasm rent in the rocks. It is in no wise connected with any supposed volcanic upheaval in the Mendips or elsewhere. But it is the result of that continuous fretting of the stream over its rocky bed, which gives rise to special denudation, and which I have likened to the action of a file. Nor is this result any whit more remarkable, from a geological point of view, than the vast amount of general denudation which has removed so great a mass of Mesozoic rock from the country between Bath and Bristol.

7.—*The Clifton Fault.*

The strata of the Avon Gorge do not present an unbroken

succession. On entering the gorge we have near Windsor Terrace, Millstone Grit. Then follow the Upper Limestone Shales, dipping to the S.E. or up stream at an angle of about 27°. After this comes the massive Mountain Limestone, on which the buttresses of the Suspension Bridge are built. As we walk through the gorge beneath the bridge, we pass through a considerable thickness of this rock. But just beyond the Clifton Station, there is a sudden change. Abutting against the Mountain Limestone are much contorted red grits and Limestone Shales. And if we ascend to the Observatory Hill, we pass, in a few paces, from Mountain Limestone on to Millstone Grit.

This sudden change is the result of the Clifton Fault, which crosses the Avon at this spot. By it the strata which lie to the N. of it are shifted downwards. Taking as a datum point the intersection of the line of fault and that of high-water mark, the rocks relatively shifted downwards are :—

On the Gloucester Side.

Mountain Limestone	... ...	710 feet.
Upper Limestone Shales	... ...	440 „
Total	... ...	1150 „

The total thickness of the upper Limestone Shales is 600 feet, so that above high-water mark there are some 160 feet, in vertical thickness, of these beds, which will extend to a height of some 180 feet or so above the river, and above them the Millstone Grit comes in near the top of Observatory Hill.

Since the fault cuts across the strata somewhat obliquely (namely at an angle of about 5° with the strike of the beds), lower beds of Mountain Limestone are intersected on the Leigh side than on the Clifton side. Hence the thicknesses of

Mountain Limestone, and Upper Limestone Shales, relatively shifted downwards, are not the same as on the opposite shore. They are:—

On the Somerset Side.

Mountain Limestone	... ...	770 feet.
Upper Limestone Shales ...	...	330 „
Total	... ...	1100 „

The difference of 50 feet in the total may be due to the dying out of the fault westwards, or it may be due to errors of observation. Since the total thickness of the Upper Limestone Shales is 600 feet, of which 330 are faulted down below high-water mark, there remains a thickness of 270 feet above high-water mark, which will extend to the top of the gorge in Leigh Woods. We should not expect therefore to find Millstone Grit on this side of the river. Nor have I been able, on careful search, to discover any of the characteristic beds of this rock, though several of the silicious bands of the Upper Limestone Shales—similar to those which are now being blasted in the river bed—crop out at the surface.

Now the Upper Limestone Shales, brought down to the N. of the fault, are softer than the massive Mountain Limestone which bounds them on either side. We should therefore expect, on the principles of denudation, that these softer rocks would have their physical expression in the contour of the land. And this is so. A marked depression, largely occupied with Dolomitic Conglomerate, separates Clifton Down from Durdham Down. And if we look across from Leigh Woods to the opposite side of the river we see that, between the bold bluff of Limestone of Observatory Hill, and the Limestone Cliffs of the Great Quarry, there is a wide space where the slope is more gentle. And this is the space occupied by the Upper Limestone

Shales. The new Zigzag path lies in a notch cut in the Limestone, from the point of junction at the edge of Durdham Down of the Mountain Limestone and the Upper Limestone Shales.

If, on the other hand, we look across from Observatory Hill, towards the Leigh Woods, we shall see to our left the beautifully-wooded cleft of Nightingale Valley; then follows a second face of limestone, which abuts against the Upper Limestone Shales brought down by the fault. The slope then becomes more gentle, for here we are in the softer shaley beds. The solid limestone is seen rising from the river bed near the railway tunnel; after which there are bold quarried limestone faces.

If we cross to the Somersetshire shore and ascend Nightingale Valley, we shall probably notice that, about half way up, the path becomes decidedly less steep. The valley also opens out and becomes wider. Here it is, I believe, that the fault crosses the valley. If, at this point we ascend the right (N.) side of the valley into Leigh Woods, we find the end of a vallum thrown up by the Britons in making their Leigh Woods entrenchment. And if we follow this camp vallum we find that it leads to the edge of the limestone bluff, which abuts against the Upper Limestone Shales faulted down. The vallum, in fact, marks the line of the fault.

Returning to Nightingale Valley and following it up, we find that it passes into a line of depression which forms a well-marked dip in the Abbot's Leigh Road, crosses Ashton Park and Beggar's Bush Lane, and so leads up to Hill Farm.

It is interesting to notice that the line of drainage, after following the line of the Upper Limestone Shales for awhile, deserts that line and passes down Nightingale Valley, thus cutting off a triangular wedge of limestone between the line of fault and the line of Nightingale Valley—a wedge which the Britons had only to fortify on its faulted side to convert it into

an almost impregnable camp. I think this is due to a dislocation of the strata along the line of Nightingale Valley. This is seen also on the Clifton side of the river in the precipitous face of limestone which overlooks the little recess in which lies the Clifton Station. Such a dislocation, probably following a joint plane, is scarcely to be wondered at in the immediate neighbourhood of so well-marked a fault.

The question naturally arises, Can we trace the fault further W.? Between Hill Farm and the Lower Limestone Shale depression there is no evidence of its existence. Nor should we expect to find such evidence. For since the fault cuts the strata obliquely, beyond Hill Farm no Upper Limestone Shales would be faulted down to the surface; but the upper beds of Mountain Limestone would be faulted down against the lower beds of the same rock. There would be no difference in hardness of the beds to produce differential denudation. But when we reach the depression of the Lower Limestone Shales, we have, I think, evidence of the existence of the fault. There is, in this line of depression, just where the road from Hill Farm descends into it through a little notch in the Down, a wooded island of Mountain Limestone. This I believe to be part of a wedge of limestone let into the Lower Limestone Shales, just as the wedge of Upper Limestone Shales is let into the Mountain Limestone further E. And if this be so there must be a corresponding wedge of Lower Limestone Shales let into the Old Red Sandstone; of the existence of which I have some evidence, from the nature of the stones ploughed up in the fields at this spot.

Owing to the overlying cover of Mesozoic rocks it is impossible to trace the eastward extension of the fault.

8.—*The Gloucestershire Tributaries.*

Our object being to trace the influence of geological structure on the contouring of the land, we must not omit to notice even

minor points which may serve to illustrate it. The gully, for example, near the Sea Wall, is in this respect of interest. It will be seen to owe its existence to a band of soft shaley beds (which might be locally termed the Middle Limestone Shales) which here occur in the Mountain Limestone. These beds being more readily denuded than the massive limestone have given origin to a line of drainage. The water which has flowed along this line of drainage has cut its way downwards, from the point of junction of the softer and harder beds on the surface of the Down, into the solid limestone. Thus the notch was *started* in the Middle Limestone Shales, but has been carried down into the underlying Mountain Limestone. A very similar gully may be seen on the other side of the river, entering the Avon a little further down stream. It is worth noting that the Middle Mountain Shales form a more gentle and more retreating slope than the harder limestone on either side. And this can be seen on both sides of the Avon. In fact this band of Middle Limestone Shales is most valuable to the geologist as completely disproving the hypothesis of a fault *along* the Avon Gorge. The beds answer point for point on either side of the river. There is no displacement—no dislocation of the beds.

The most important tributary on the Gloucester side of the Avon is the Trym, which falls into the river at Sea Mills. Close to its mouth it receives a Stoke branch. This branch rises in the softer band of Old Red; and, from the present contour of the land, it would seem its natural course to follow this line of depression to the Avon. But instead of doing so, it leaves the line of depression and cuts a prettily wooded valley through the Dolomitic Conglomerate, which may be seen near the head of the notch to rest on the Old Red. Thus the Stoke Trym does on a small scale exactly what the Avon does on a large scale. The natural course of the Avon from Bristol would seem to be to flow into the sea by Nailsea, thus avoiding altogether the ridge

of the Downs. Instead of doing so, its cuts a notch through the Downs. The natural course of the Stoke Trym would seem to be to follow the line of the softer Old Red depression. Instead of doing so, it cuts a notch in the Dolomitic Conglomerate. In each case the explanation is the same; not that a rent has been formed in the ridge to meet the special needs of the stream, but that the notch in the ridge, and the wider and more general depression above the ridge, are the different products of different modes of denudation. The one is due to special denudation; the other to general denudation. When the stream began to cut its notch into the ridge, the ridge *as such* had no existence.

Above the point at which the stream is joined by the Stoke branch, the valley of the Trym is a notch of no very great depth, but with the characteristic vertical cliff which is generally to be seen on one side or both of the valleys cut down into the Dolomitic Conglomerate. Here it calls for no further remark. But near the point of junction of the Henbury and Westbury branches, it is worth noting that it flows in a line of depression of Lower Limestone Shales between the Mountain Limestone ridge and the Old Red hill upon which Coomb House is situated. The Henbury Trym when it emerged from the Mountain Limestone took the course of least resistance through a depression long ago formed in the Lower Limestone Shales, and subsequently filled in with Dolomitic Conglomerate.

The Westbury branch rises in the Mountain Limestone, or rather in the Lias that rests upon it, N.E. of the village of that name. It does not present any features that call for notice.

The Henbury branch, on the other hand, is of great interest. It again exemplifies the notching of a ridge by special denudation. Rising in the Rhœtic some two miles to the N. of Henbury, its natural course, on the present configuration of the land, would seem to be, to flow W., over comparatively low ground, to the Severn. But instead of doing this, it boldly makes for the

limestone ridge, and cuts the deep trench of Coomb Dingle, through the Blaize Castle woods. It is scarcely necessary again to point out that this is due to the fact that the low ground above is due to the action of general denudation, and that its gradual lowering was effected during, and not before, the time that the Henbury Trym was exerting its special denuding influence on the Blaize Castle ridge.

It only remains in this connection to point out that the depression to the South of the Blaize Castle eminence may be due to the incoming of the Middle Limestone Shales at this point.

There is one other minor depression on the Gloucester side of the Avon, namely that in the Lower Limestone Shales S. of the Penpole Down. Here we have evidence, from the way in which the Dolomitic Conglomerate is disposed (*see map*), that the Old Red Sandstone ridge was notched before the deposition of that Triassic deposit.

9.—*The Curves of the Avon.*

The curves and bends of the Avon, as it passes through the Clifton Gorge, and thence to the Severn, are of interest. Mr. Tawney suggested that in the limestone they might have been determined by joint planes. But the point to which I would rather draw attention is that they are very closely connected with the incoming of harder and softer beds.

From the beginning of the Gorge to somewhat beyond the the Suspension Bridge, the river cuts across the strata nearly along the line of their dip. Then it is forced over somewhat to the Somerset shore, probably by the incoming of those upper and harder beds of the Upper Limestone Shales which, as we have seen, are more extensively brought down by the fault on the Clifton than on the Leigh side of the river, and are now being blasted in the river bed near the Gloucester shore.

After crossing the band of the Upper Limestone Shales brought down by the fault, the Avon meets with, and would seem to be deflected on to the Gloucester shore by, the solid Mountain Limestone which was long ago extensively quarried away from this point so as to open out a better view along the river for the sake of its safer navigation. The deflection is, however, only temporary. The river meeting on the Gloucester shore with similar solid limestone (a little further down stream on this side of the river than the other) resumes its original course, cuts across the Middle Limestone Shales, but is strongly deflected to the W. by the incoming of the massive limestone beyond these softer beds.

Beyond this a band of alluvium on the Gloucester shore points to the fact that, even in recent geological times, the river has been eating into the Old Red banks of the opposite shore. This, however, ceases with the incoming of the tough Dolomitic Conglomerate; and the river cuts a tolerably direct course in its original N.W. direction until it meets with, and is boldly deflected by, the Old Red, south of the Penpole ridge.

The question here suggests itself: Why should the river have been deflected by this ridge and not have cut boldly across it as in the case of the Leigh-Durdham ridge? I imagine that the answer to this question is to be found in the fact, that the Avon was here under the influence of that S.W. slope of the land of which the Trym gives us unmistakeable evidence. Be this as it may, the river is here turned nearly at right angles; and as it flows to the S.W. encroaches further and further upon the constantly thicker beds of the Dolomitic Conglomerate, meeting with more and more resistance until, at Hung Road, near Pill, it is once more deflected, across the softer Trias Marls, to the Severn.

10.—*The Somersetshire Tributaries.*

Setting aside the gully caused by the Middle Limestone

Shales, and a little gully marking the point where the Lower Limestone Shales cross the Avon, there are five tributary streams on the Somersetshire side of the Avon.

The first, which I have marked on the map as the Leigh Brook, collects the rainfall in a Lower Limestone Shales depression N.E. of Abbot's Leigh, and in a depression of the Limestone on the Leigh Court estate. The two depressions join near the keeper's lodge, whence the little stream flows in a prettily wooded notch of the Old Red Sandstone until it reaches the Avon.

The second, which I have marked as the Oakham Brook, answers to the Stoke Trym on the Gloucester side of the river; but with this difference, that it follows the depression to the Avon and does not cut a gorge in the Dolomitic Conglomerate, which steeply bounds it on the W., resting on the upturned edges of the Old Red.

The third, or Chapel Brook, collects the rainfall from the Lower Limestone Shales depression S. of Abbot's Leigh, in the manner shown in the map. It then leaves this depression, and notches the Old Red Sandstone ridge, near the N. side of which it is dammed back to form the Abbot's Pool. After this its valley opens out, right and left, as it crosses the softer Old Red rocks, and it receives a little tributary from the W., the depression being less marked on the E. owing to the overlie of Dolomitic Conglomerate. After crossing this depression, the valley of the Chapel Brook narrows to a wooded cleft as it passes through the harder Dolomitic Conglomerate; opens out again where the softer Triassic Marls come in; and narrows once more in the harder Dolomitic Conglomerate through which it finally passes to the Avon.

The fourth, or Markham Brook, follows a very similar course. It collects its head-waters from the Leigh Downs, and from the E. and W. depression of the Lower Limestone Shales. It, too,

then notches the harder Old Red, flowing in a narrow valley, which widens out in the softer Old Red, and here receives a tributary from near Failands House, and a smaller intermittent streamlet from the E. Its valley, too, then narrows to a wooded cleft, as it passes through the harder Dolomitic Conglomerate, giving rise to Markham Bottom; opens out in the Triassic Marls above Pill; and then narrows again in the Dolomitic Conglomerate, just before it falls into the Avon.

Nothing could be more beautiful than the way in which these two streams, the Chapel Brook and the Markham Brook, exemplify the differential action of general and special denudation. Where the rocks are hard the valleys are narrow, for here general denudation cannot keep pace with special. Where the rocks are soft the valleys open out, for here general denudation has greater power. At the present relative level of sea and land, the special denudation is going on very slowly, or has almost ceased. But were the land to be elevated to a greater height above the sea level, the more rapid streams would cut their way downwards far more rapidly into the rocks over which they run. In times past, no doubt, at periods of greater rainfall, the streams were more active agents of denudation than they could be with their present dimensions. A more rapid fall, and a larger water supply, probably marked the period of the greatest activity of these streams.

The fifth and last stream, the Easton Brook, rises in the softer Old Red beds and then notches the Dolomitic Conglomerate, at first so deeply as to expose the underlying Old Red Sandstone. After emerging from the constricting Dolomitic Conglomerate, it passes through Trias Marls, and finally over the Severn flats to join the Avon a little S. of Avonmouth.

The lover of nature will find the tracing of such streams as these, downwards from their source, a most delightful occupation.

The notches in the harder rocks are beautifully wooded; their banks, in this early Spring-time, are thickly carpeted with bright Spring flowers, while the whole air seems resonant with the notes of song-birds.

11.—*Conclusion.*

I have thus tried to explain how the physical features of the district N.W. of Bristol are determined, in general and in detail, by the geological structure; and how all these features are the product of denudation, general and special.

That the Avon Gorge itself is a product of denudation was, as we have seen, long ago pointed out by Professor Jukes. But there still remain sceptics even in the ranks of geologists. My main object in this paper has been to enforce the truth of this explanation by showing that it applies to *all the minor gorges* through which the tributaries of the Avon flow. And I would invite the sceptics to consider, first, the case of such minor notches as are cut by the Chapel Brook and the Markham Brook; then such an one as is cut by the Stoke Trym; then that much more marked gorge which is cut by the Henbury Trym through the Blaize Castle limestone ridge; and finally rise from this to the Avon Gorge itself. If they still remain sceptics, I must confess my incompetence to help them to rise into orthodoxy. I can only assure them that the hypothesis of any faulting action along the line of the gorge is completely out of the question. That is proved by the Middle Limestone Shales.

The Clifton Gorge, the result as I contend of special denudation, forms so striking a physical feature that it cannot be overlooked. It appeals at once to the imagination. The results of general denudation, on the other hand, do not affect us in the same way. It is only the geologist who can rightly estimate these results. We cannot so readily realise the *absence* of vast masses

of rock, over a wide area of country, as the *presence* of a definite ravine, like the Clifton Gorge. And yet it seems to me that the general denudation which has removed all the Inferior Oolite, not to mention the newer rocks which almost certainly overlaid it, and nearly all the Lias, from our district, demands almost more of our wonder, and our faith in geological principles, than the special denudation which has cut for us the Avon Gorge. Assuredly if we must call upon an inexplicable convulsion of nature to explain the one, we must in like manner call upon a yet more inexplicable convulsion of nature to explain the other.

Finally we must remember that this vast system of denudation yet in progress has revealed to us the effects of a pre-Mesozoic denudation equally vast. Our limestone Downs and our Old Red ridges are physical features which have been *rather reproduced* than produced by our present system of denudation. For long ages these ridges, carved out by the older denudation, lay buried beneath a load of Mesozoic rocks. To remove this load has been the main work of the present system of general denudation, while special denudation has been cutting those notch-like gorges, which break the continuity of the ancient ridges.

NOTE.—I have to express my thanks to Sir Philip Miles, Sir Greville Smyth, and Mrs. Harford for kindly giving me permission to wander at will through their estates.

The section on the Clifton Fault covers the same ground as my paper to be published in the May number of the Quarterly Journal of the Geological Society of London.

The Fungi of the Bristol District.

PART VIII.

By CEDRIC BUCKNALL, Mus. Bac.

TRICHOLOMA.

1085. Agaricus lascivus, *Fr.*, *var.* robustus. — Failand, Sept. 1884. Coombe Hill, Autumn, 1883.

OMPHALIA.

1086. Agaricus muralis, *Sow.* — Durdham Down, „ 1884.

ENTOLOMA.

1087. Agaricus repandus, *Bull.* — „ Sept. „

CLITOPILUS.

*Agaricus vilis, *Fr.*, *Cooke, Illustrated t.* 487.

Figured from the Leigh Down specimens, where it occurs abundantly nearly every year. No. 710 is this species, not *Ag. asprellus*.

HEBELOMA.

1088. Agaricus capniocephalus, *Bull.* — Blaise Castle Woods, Aug. 1884.

NAUCORIA.

1089. Agaricus striaepes, *Cooke, Grevillea*, vol. 13, p. 60, *Illus. t.* 478. — Westbury, Oct. 1877.

Plate III.

C. Bucknall. del. ad nat.

Robinsons.

1. *Cortinarius papulosus*, Fr.
2. *Paxillus panaeolus*, Fr.
3. *Cortinarius croceo-caeruleus*, Pers.

[redacted]

Plate IV.

Cortinarius macropus, Fr.

C. Bucknall, del ad nat

1. Cortinarius arvinaceus, Fr.
2. Cortinarius quadricolor, Fr.

	HYPHOLOMA.		
1090.	Agaricus leucotephrus, *B. & Br.*	Blaise Castle Woods,	Sept. 1884.
1091.	Coprinus cinereus, *Schaeff.*	Stapleton	,, ,,
	PHLEGMACIUM.		
1092.	Cortinarius glaucopus, *Fr.*	Durdham Down,	Sept. ,,
1093.	,, fulgens, *Fr.*	,,	,, ,,
1094.	,, croceo-caeruleus, *Fr.*, Plate III., fig. 3.	,,	,, ,,
	*Cortinarius papulosus, *Fr.*, (No. 1042, *ante*), Plate III., fig. 1.	,,	Oct. 1883.
	MYXACIUM.		
	*Cortinarius arvinaceus, *Fr.* (No. 1043, *ante*), Plate V., fig. 1.	Blaise Castle Woods,	Oct. 1882.
	TELAMONIA.		
1095.	Cortinarius macropus, *Fr.*	Leigh Wood,	Oct. 1884.

Pileus fleshy, convex and incurved, then expanded, obtuse, *hoary with minute squamules*; stem solid, tall, equal, fibrillose, becoming white, ring thin, distant; gills adnexed, distant, very broad, pallid then watery cinnamon. *Fr. Hym., Eur. p. 374.* Plate IV.

	°Cortinarius quadricolor, *Fr.* (No. 1046, *ante.*) Plate V., fig. 2.	Blaise Castle Woods,	Oct. 1882.
	HYDROCYBE.		
1096.	Cortinarius subferrugineus, *Fr.*	Blaise Castle Woods,	Sept. 1884.
1097.	Paxillus lepista, *Fr.*	Frenchay,	,, ,,
*	,, panaeolus. *Fr.* (No. 957, *ante*), Plate III., fig. 2.	Blaise Castle Woods,	,, 1882.
1098.	Russula nitida, *Fr.*	Stapleton.	,, 1884.
1099.	Marasmius amadelphus, *Fr.*	Durdham Down,	Aug. ,,
1100.	Polyporus ribis, *Fr.*	Leigh Wood,	June, ,,

1101. Thelephora cæsia, *P.* — Tortworth, July, „
1102. „ arida, *Fr.* — Coombe Hill, Nov. „

Spores elliptic, echinulate, brown, ·009 mm. long.

1103. Dacrymyces stillatus, *Nees.* — Abbot's Leigh, April, 1885.
1104. Actinothyrium graminum, *Kze.* — Durdham Down, May, 1884.
1105. Vermicularia trichella, *Grev.* — Leigh Wood, June, „
1106. Diplodia sapinea, *Fr.* — Haw Wood, Mar. 1885.
1107. „ Rubi, *Fr.* — Durdham Down, May, 1878.
1108. Hendersonia loricata, *Sacc. & Roum.* — Stapleton, Mar, 1880. Brentry, April, 1885.

Perithecia gregarious, innato-erumpent, corticolous, globulose, pierced, ¼-½ mill. diam.; structure minutely cellular, fuligineous; spores ovoid, obpyriform, ·022-·028×·015-·016 mm., rounded at the apex, 2-3 septate, not constricted, fuligineous, at first nucleate, borne on filiform, hyaline basidia, which are ·010-·015×·002 mm. *Sacc. Syl., No. 2410.*

On beech branches.

" Not a good species of *Hendersonia.*" *M. C. C.*

1109. Cytospora pinastri, *Fr.* — Abbot's Leigh, April. 1885.
1110. Synchytrium taraxaci. *De By. & Wor.* — Stoke, May, 1883.
1111. Mitrula paludosa, *Fr.* — Abbot's Leigh, April, 1885.
1112. Peziza acetabulum, *L.* — Tortworth, July, 1884.
* „ leucomelas, *Pers.* — Ashton, Feb. 1878.

Recorded as *P. acetabulum* at p. 348, vol. II., part II.

1113. Peziza hæmastigma, *Fr.* — Frenchay, Feb. 1884.
1114. „ melastoma, *Sow.* — Hanham, Mar. „
1115. Lophium (Mytilidion) decipiens, *Karst.* — Black Rock Quarry, Mar. 1885.

Perithecia gregarious, sessile, erumpent then superficial, rounded or oblong, sub-navicular, acutely keeled, black, even, minute, scarcely exceeding ·8 mm., asci cylindrical, often slightly inflated and curved towards the base, octosporous, ·065-·08×

·008-·012 mm.; spores in the lower part of the ascus distichous, fusoid-oblong or fusoid-elongated, straight or moderately curved, 8-septate, pale yellow, ·015-·02 × ·004-·006 mm.; paraphyses filiform, flexuous, slender. *Sacc. Syl., No. 5703.*

On bark of *Juniperus communis*, and fir cones.

My specimens are on pine wood.

1116.	Colpoma quercinum, *Wallr.*	Haw Wood,	Mar. 1885.
1117.	Eutypa flavo-virens, *Tul.*	Clevedon,	June, 1884.
1118.	„ rhodi, *Fckl.*		
1119.	Diaporthe pulla, *Nits.*	Brentry,	Mar. 1885.
1120.	„ protracta, *Nits.*	Leigh Woods,	April, 1882.
1121.	„ acus, *Blox.*	Black Rock Quarry,	Mar. 1885.
1122.	„ Arctii, *Lasch.*	The Avon, S.	April, „
1123.	„ discors, *Sacc.*	Black Rock Quarry,	Mar. „

On dead stems of *Rumex*. Readily distinguished from *D. acus* by the black line which encircles the groups of perithecia, and which is entirely absent in the latter species.

1124.	Diaporthe incarcerata, *B. & Br.*	Leigh Down,	April, 1882.
1125.	Diaporthe blepharodes, *B. & Br.*	„ „	„ 1883.
1126.	Diatrype strumella, *Fr.*	Leigh Wood,	June, 1884.
1127.	„ disciformis, *Fr.*	„ „	(?)
1128.	Valsa stellatula, *Fr.*	Near Blaise Castle,	April, 1885.
1129.	„ syngenesia, *Fr.*	The Avon S.	Feb. „
1130.	„ microstoma, *Fr.*	The Gully.	
1131.	„ coronata, *Fr.*	Near Blaise Castle,	April, 1885.
1132.	„ Curreyi, *Nits.*	Haw Wood,	Mar. „
1133.	„ abietis, *Fr.*	Abbot's Leigh,	April, „
1134.	„ salicina, *Fr.*	Abbot's Leigh,	Mar. „

1135.	„ (Pseudovalsa) aglaeostoma, *B. & Br.*	Leigh Wood,	May, 1882.

On twigs of *Viburnum lantana*, but it appears to be the same as that described as growing on elm twigs.

1136.	Valsa (Coronophora) angustata, *Fckl.*	Brentry,	Mar. 1885.

Perithecia sometimes numerous, disposed in orbicular or oval sori, which are barren in the centre, sometimes few only, circinating, or lastly, altogether solitary, irregularly scattered, concentric or symmetrical, erect or almost decumbent, ovate or globose, rather large, at length collapsing, more or less verruculose, black, glabrous, without a neck, pierced at the apex, often erumpent through the variously fissured epidermis, sessile on the surface of the inner bark, more rarely with the base immersed in its outer layer; asci broadly obovate, very obtuse at the apex, often ventricose at the base, formed of a rather thick membrane, abruptly attenuated into a narrowly filiform pedicel, which is generally five or even six times longer than the sporiferous part, ·032-·036 × ·014-·016 mm. (p. sporif.), the cavity of the asci, or more rarely the asci themselves, narrowed below the apex; spores very numerous, crowded, cylindrical, nearly straight, ·004-·008 × ·001 mm. *Sacc. Syl., No. 414.*

On branches of beech.

1137.	Valsa (Cryptospora) Betulæ *Tul.*	Leigh Wood,	Feb. 1877. May, 1885.
1138.	Massaria pupula, *Fr.*	Brentry,	April, „
1139.	„ eburnea, *Tul.*	Leigh Wood,	„ „
1140.	Xylosphæria apiculata, *Curr.*	Near the Avon, S.	Dec. 1884.
1141.	Sphæria (Rebentischia) unicaudata, *B. & Br.*	Brentry,	April, 1885.
1142.	Sphæria (Didymella) sepincolaeformis, *De Not.*	Brentry, The Avon, G.	„ „ May, „

Covered by the epidermis, scattered, causing a black spot, encircled with a pallid halo, perithecia lenticular, rotund, thin, black, opening by a scarcely conspicuous ostiolum; asci clavate,

octosporous; paraphyses filiform, rather thick; sporidia oblong-pyriform, hyaline, bilocular, lower cell small. *Sacc. Syl. No. 2150.*

On branches of rose, asci ·1 mm.; sporidia ·023-·025 × ·0095 mm.

1143. Sphæria (Metasphæria) corticola, *Fckl.*	The Gully,	Feb. 1880.

Perithecia scattered, minute, nestling under the swollen, and, at length, splitting epidermis, globose, black, nucleus grey, at length empty; ostiola scarcely prominent, very short; asci stipitate, cylindrical, ·096 × ·01 mm.; sporidia eight, uniseriate, oblong, obtuse at each end, 3-septate, slightly constricted at the septa, ·016 × ·006 mm. *Sacc. Syl., No. 3442.*

On twigs of sloe.

1144. Sphæria (Metasphæria) Cumana, *Sacc. & Speg.*	Aust,	June, 1881.

Notes on a Common Fin Whale
(*Physalus antiquorum*, Gray,)
lately stranded in the Bristol Channel.

By E. WILSON, F.G.S.

(Curator of the Bristol Museum.)

ON January 15th, 1885, a large whale was washed ashore dead, at Littleton Pill, an inlet on the east side of the estuary of the Severn, and about five miles north of the Severn Tunnel. The whale was first observed by the foreman of Mr. G. Wintle, brick manufacturer, Elberton, who had it towed up the inlet and moored to the wharf near his brickyard, at some little distance from the shore. On visiting the spot two days afterwards, I found the animal lying on its back at the bottom of the Pill. Though not then able to examine the body closely, I saw enough to satisfy me that this whale belonged to the group of Cetacea termed the *Balænopteridæ*, or Finner Whales, and to the species popularly known as the Common or Great Northern Rorqual—the Razorback or Fin Whale of the whalers—and scientifically as *Physalus antiquorum* (Gray), or *Balænoptera musculus* (Fleming).*

* To avoid mistake, I may remark that these are some of the best known names among a long list of aliases. See Catalogue of Seals and Whales in the British Museum, by Dr. J. E. Gray, F.R.S., 2nd ed., 1866, p. 144.

Eventually the animal was taken to Bristol.

The following details as to the external characters and the dimensions of this great whale are the result of a careful examination of the body since its arrival in that city:—The animal was a female of about the average size, the total length of the body being 66 ft. The belly (*i. e.*, the ventral surface of the throat and thorax) was traversed by numerous longitudinal shallow grooves, parallel to one another, running backward from the inner edges of the lower jaw beneath the pectoral fins, and ending posteriorly along two lines drawn obliquely from beneath the pectorals to a median point ventrally about 9 feet behind their termination. Occasionally adjoining grooves blended with one another, uniting obliquely. The colour of the body was black above, *i. e.*, on the head and jaws, back and sides, down to an irregular line passing from beneath the lower jaws and the pectoral fins to the termination of the tail ventrally. Below, the body was white, namely on the belly and also on the abdomen and ventral surface of the tail along a triangular shaped area having its apex at the tail-fork. When the whale was found the white colour of a good deal of the belly region was tinged with a deep pink, owing to the rosy-coloured epidermis which in this species lines the hollows of the ventral plicæ. By the time the animal reached Bristol, however, this pink colour had entirely disappeared, apparently as a result of the decomposition then rapidly progressing. The lateral portions of the white belly region were mottled with a few large irregularly shaped, dark patches, an especially large one lying beneath each pectoral. The black colour of the dorsal region shaded off gradually into the white below. In the white area bordering the dark region there were, in addition to the larger patches above mentioned, occasional dark spots and dashes in the ventral grooves. In the posterior portion of the body (tail) the two diversely coloured regions were more sharply defined.

The epidermis was thin and easily rubbed off; thus the dark pigment it contains may be lost through a little friction and parts appear white which in the living animal are black. Seeing that the whale was lying on its back I had not a good opportunity for studying the dorsal features. The head had a very depressed and flattened contour, I should estimate its length at about 17 feet. There was not, however, visible any external sign of division between the head and the trunk. In the position in which the animal lay the back appeared almost flat; in life it would present a regular and depressed curve from the snout to the tail-fork, broken only by the prominent dorsal fin. The caudal portion of the trunk was much compressed laterally, and had a proportionately great vertical depth —a very characteristic feature of this whale and its immediate allies.

The pectoral fins (flippers) were given off 21 feet behind the nose; they were of moderate length (7 feet as measured along their lower edge), lanceolate in shape, and in colour black exteriorly and probably interiorly also in the living state.* The dorsal fin was set far back on the tail, its commencement and termination being respectively 49 feet from the nose and 14 feet in front of the tail-fork; it was prominent, erect, and compressed laterally. The horizontal tail-fin had a considerable breadth of union with the hind end of the body. One lobe is convex and the other concave, thus giving to this fin the characteristic screw-shaped contour. Each lobe projected seven feet from the body, giving a total span for this powerful organ of propulsion of no less than fourteen feet.

The eye was extremely small relatively, and at a slight distance hardly discernible. It is placed on a prominent part of

* When I examined the animal in Bristol the inner surface of the pectorals appeared to be white. As to this, however, note what is said above in regard to loss of colour.

the head a little above the angle of the mouth. In figures of this, as probably also in those of several other whales, its size is greatly exaggerated. The blow-holes I could not see owing to the position of the animal. The sexual orifice was placed almost directly beneath (just in front of) the dorsal fin. The anus was immediately behind.

The jaws were of about equal length, the lower jaw *very slightly* projecting. In describing a male whale belonging to this species, 61 feet in length, stranded near Portsmouth in 1868, Dr. W. H. Flower, F.R.S., states that the lower jaw projected eighteen inches beyond the upper.* In this respect the Littleton whale certainly differs from the Portsmouth whale, the jaws being practically of equal length. The upper jaws are much narrower than the lower, and run pretty straight forwards to the pointed nose. The upper jaws are lined with baleen (whalebone) running all round a little within their outer margin. The baleen consists of numerous thin and closely set plates, imbedded in the gum of the upper jaws, from which they are suspended vertically. They are arranged transversely to the long axis of the jaw, on each side, in several (four) continuous series, which rapidly diminish in size inwardly, thus giving the whole palatine surface (with the exception of a smooth median ridge which is not occupied by whalebone) an elegant arched form. Into this arch, when the mouth is shut, fits the animal's enormous tongue. The baleen plates are *slightly* curved, the convex surfaces being directed forwards. On removal from the body they shrink somewhat in drying and thus acquire a more pronounced curvature or spiral twist. The baleen plates vary considerably in different parts of the jaw, both in form, size, and colour. They are generally of a triangular shape (viz., an acute right-angled triangle with the long side of the right angle

* P. Z. S., 1869, p. 604, pl. xlvii., f. 1.

exteriorly, the hypoteneuse curved and interiorly, and the short side forming their attached base) and taper away to a point at their free ends. Their inner edges are fringed with more or less elongated bristle-like fibres, of a yellowish white colour. These bristles are the prolongations of the stout fibres of which the baleen plates consist, *minus* the investing layers of enamelled substance which cover those plates. This bristly portion becomes proportionately greater as the plates become less. The outer and principal series of baleen plates (the labial plates) attained their maximum dimensions both in length and breadth near the middle of the jaws. They were here fully 2 ft. 6 in. long, from 9 to 10 inches broad at their base, and $\frac{1}{10}$th of an inch in thickness. In a general way they are of a pale greenish grey colour, with alternating dark and light coloured longitudinal (*i. e.*, vertical to the base) streaks at pretty regular intervals. Taking one of the largest plates as a typical example, we notice that its outer portion for a width of three or four inches is of a dark slate colour, with hardly perceptible streaking, whilst the remainder of the plate for a width, at the base, of six or seven inches, is of a pale grey with, at first, several narrow horn-coloured streaks at regular intervals, and then with a few alternating broader and less regularly distributed cream-coloured bands edged with dark linear streaks, which prevail until the inner edge is reached. Such a plate is quite a striking object. The baleen plates diminished in size regularly, or rather in a graceful curve, and became paler in colour, going towards the snout; they also diminished in size and became whiter in colour towards the mouth angles. At the snout the plates were not more than five or six inches in length by two inches in breadth, and were here entirely of a yellowish white colour. The whale-bone of this as of the other Finner whales is of very little commercial value, being only used to split up into an inferior kind of false bristles. It is, however, of considerable scientific interest,

[redacted]

and furnishes important characters for the discrimination of the different species.

When I first saw the whale at Littleton Pill, although it was then in the middle of winter, and the temperature was very low, scarcely indeed above the freezing point, decomposition had already set in. As a consequence of this the "belly" had become enormously distended, and the by no means ungraceful form of the animal had become greatly distorted. An accurate delineation of the whale as seen in the living state was therefore impossible. Fortunately several photographs were taken. The accompanying figure is a platinotype produced from a negative taken by Mr. F. A. Orchard, Photographer, Stapleton Road, Bristol, on the 26th January, eleven days after the animal's discovery. Allowing for the unavoidable distortion of the anterior portion of the body from the cause mentioned above, it faithfully represents the whale, or at any rate its latero-ventral aspect. The men in charge informed me that the distension of the animal had, to a great extent, taken place since it had been first observed. What the cause of death of this whale was it is impossible to say. Seeing that its body was stranded on a shore at some distance from the nearest coast (Cornwall) ordinarily frequented by these animals, and that it had already begun to decompose, the probability is that it had been dead some little time, several days at least, I should say, and had subsequently been floated up the estuary with the tide. The animal lay in the Pill for about a fortnight. During this period, as also after reaching Bristol, it was visited by many thousand people, for whose accommodation special trains were run by the Midland Railway Company. The body was claimed by the lord of the manor, and also by the agent for the Crown, as "flotsam and jetsam." The latter carried the day and sold the carcase by public auction, when it was knocked down to Messrs. Kent and Cottrell, Artificial Manure Manufacturers, of Bristol, for the

sum of £40. On January 29th the enterprising purchasers had the whale towed down the estuary and up the river Avon by a steam tug, and subsequently by six horses to their works at St. Philip's Marsh, Bristol. Here, having floated the monster ashore with a high tide and enclosed it within a hoarding, they exhibited it to the public for about a fortnight. The animal was then cut up, the flesh being converted into animal manure, whilst the skeleton has been preserved as an anatomical specimen.

On the newly-discovered Phenomenon of Apospory in Ferns.

By CHARLES T. DRUERY, F.L.S.

I HAVE been invited to address you this evening with the object of bringing before your notice certain new phenomena of reproduction which have been recently discovered upon two of our native British ferns. My personal observations, however, relate more especially to one of these ferns, viz., *Athyrium Filix-fœmina,* var. *Clarissima,* an exceedingly beautiful variety found growing wild in North Devon, for whose present existence we are indebted to Colonel Jones, of Clifton, who detected its beauty under very adverse circumstances, and saved it from destruction, to which it had been doomed by the neglect of the original finder.

Before, however, I proceed to explain to you the nature of the phenomena in question, I will make a few preliminary remarks elucidating the normal mode of reproduction in ferns, since to those who have not made a special study of the subject the peculiar interest attaching to the abnormal method discovered in connection with the *Athyrium* in question may quite possibly be missed, while those who have acquired a knowledge of the various ways in which ferns propagate themselves will, I am sure, pardon the little delay which my remarks will necessitate.

In the first place, I may indicate the great difference which exists between the reproductive phenomena common to the

higher orders of vegetation, such as flowering plants, and that of the cryptogamic families to which ferns belong. In the one case the reproductive organs, viz., the flowers, are almost invariably among the most conspicuous parts of the plant, and the manner by which the process of fertilization is effected is easily investigated. The flower is provided with a very evident ovary, to which is attached the stigma: these represent the female organs. Then there are the stamens or male organs, the pollen grains from which, falling upon the stigma, develop tubes which pass down it to the ovary and fertilize it, the result being seed capable of reproducing the parent form. This seed, finding a suitable nidus, sends out roots into the soil, and leaves into the air, and the plant, without further complication, takes on the form of its parent.

With ferns, however, the process is so much more complex, and the whole of the reproductive action is conducted on a scale so excessively minute, that we cannot wonder at the slow progress which was made in the discovery of the *modus operandi*; it being in point of fact only forty years ago that the last step was attained in the investigation of the normal mode of their reproduction, by the discovery that ferns, like flowers, were the result of sexual action, Naegeli discovering the antheridia, or male organs, in 1844, and Suminski the archegonia, or female organs, two years later.

Probably one of the greatest obstacles to the earlier discovery of the true nature of the phenomena lies in the fact that the first result of the germination of a fern spore is the production not of a fern, nor anything resembling one, but of a small flat green disc, very like a young liverwort, upon the under surface of which the antheridia and archegonia are produced, and the fertilization takes place which results eventually in the reproduction of the parent fern.

In ferns, moreover, the sori or heaps of capsules containing

the spores or reproductive bodies are borne normally upon the backs of the fronds, a feature constituting one of the most salient differences between ferns and flowers, and one which for a long time threw observers off the scent regarding their true nature.

The sori in one family—the Polypods—are destitute of a cover, but in the large majority of cases are furnished with an indusium. The sorus consists of a variable number of spherical capsules, termed sporangia, which, though themselves only just visible to the naked eye, contain each a large number of absolutely microscopic bodies termed spores, very many millions of which are produced upon a fern frond of very moderate size.

When these spores are ripe, they are scattered by the sudden bursting of the sporangium, caused by the contraction of a ring, which in most cases wholly or partially surrounds it.

We here arrive at another great point of difference between ferns and flowers, the spores thus scattered differing essentially from a seed, inasmuch as they are not the product of a process of fertilization. Their function also is not that of reproducing the parent form directly, but to give rise to another form capable of bearing the equivalents of flowers, and thus bringing about that sexual action which Nature seems almost invariably to require for the perpetuation of a species.

The spore then, by a process of cell generation, develops into a prothallus, which, after the first few cells have proceeded from the spore, develops and supports itself by means of root-hairs upon its under surface. After a time the growing point stops short, and the sides grow out and on until it assumes more or less of a heart shape, at which stage, and when it is on an average from $\frac{1}{8}$ to $\frac{1}{4}$ inch across, the antheridia and archegonia may be easily detected, the former scattered among the root-hairs, and the latter clustered together upon a thickened cushion of cells in the indentation of the prothallus. The next process is the rupture of the antheridia, from which issue numerous

spermatozoids which, aided by the moisture, which in a congenial atmosphere is deposited upon the under surface of the prothallus, make their way to the archegonium and fertilize the ovary seated at its base, the result being a plant resembling the fern from which the spore originated. From this description it will be seen that the prothallus represents the flower of the higher orders of plants in so far that it bears the homologues of the stamens and stigma in the forms of the antheridia and archegonia, and also the ovary and ovum. The spermatozoids take the place of the pollen grains, but seem endowed with a certain amount of volition in addition to power of locomotion, as they have been observed to travel direct towards the archegonia, and I am informed by Prof. F. O. Bower that they have made their way unmistakeably towards simulated archegonia, consisting of minute applications of malic acid to the surface of the prothallus, a fact which points to sensory organs of some sort.

It will be seen from the preceding remarks that in the normal development of ferns the prothallus constitutes a separate generation, and it would therefore form an approach to the higher orders of plants, did the prothallus spring direct from the parent plant, instead of through the mediation of the spore; since the fern would then be the bearer, if not of flowers proper, at any rate of their homologues.

This phenomenon then, viz., the production of the prothallus upon the parent plant without the mediation of the spore—*i. e.*, apospory—is precisely that which has rendered Colonel Jones' *Athyrium Filix-fœmina*, var. *Clarissima*, so remarkable, since it is upon that plant that this peculiarity has been first observed.

In connection with this discovery I may mention that Prof. Thiselton Dyer considers that it exhausts the obvious possibilities with regard to the reproductive methods of ferns; he also recounts the various steps which have led up to it, and gives the dates and discoveries thus :—As far back as

1597	Gerarde	observed	seedling plants near parents,
1648	Caesius	„	sporangia,
1669	Cole	„	spores,
1686	Ray	„	hygroscopic movements of sporangia,
1715	Morison	raised	seedlings from spores,
1788	Ehrhardt	observed	the prothallus,
1789	Lindsay	„	germination of spores,
1827	Kaulfuss	„	development of prothallus,
1844	Naegeli	„	antheridia,
1846	Suminski	„	archegonia,

which completed the phases of the normal development.

This was followed by the discovery by Prof. Farlow, in 1874, of an abnormal mode of reproduction called apogamy, which consists in the occasional development of the fern by direct bud growth from the prothallus without the intervention of the sexual organs, a phenomenon which is the direct converse of apospory, which we are met to consider; the fern in the one case growing direct from the prothallus by a simply vegetative process, and the prothallus in the other growing in like manner directly from the parent fern.

The discovery of apospory having, however, been preceded by that of sundry other forms of proliferation upon our native Athyria, which really led up to it, I would still claim your indulgence for a few minutes in order to detail to you the successive steps in question.

In September, 1882, whilst examining a batch of very young plants, raised from spores sent me by Mr. P. Neill Fraser, of Edinburgh, I was struck by the appearance of two whitish dots upon the first frond which had risen from the prothallus of an *Athyrium*. On closer investigation with a lens, I was forced to the conclusion that they were bulbils, though I could scarcely credit it; as to my knowledge no proliferous form of *Athyrium* was known, a belief which all my enquiries at the time confirmed,

though later on I ascertained that Mr. Mapplebeck had raised plants from similar bulbils, though only the verbal record of the facts remained, and the proliferous forms had apparently not been perpetuated. Pursuing my researches, I found, about a fortnight later, another altogether different form, far more proliferous than the first, the primary frond bearing no less than seven bulbils.

In the former (*Fig.* 1), instead of the simply palmate form usually assumed by the first frond of an *Athyrium*, it is bipinnate and very foliose; the figure is, of course, immensely enlarged, the whole plant at that stage being about ¾ inch high only. The buds upon the first frond proceeded, without any dormant interval, to develop small pinnate fronds, and also aerial roots, which latter grew so vigorously that they projected themselves into a mound of soil raised at a distance of half an inch from the back of the frond. The second frond produced four buds which, however, remained dormant through the winter, the season being already far advanced when they appeared. All the buds, however, produced eventually independent plants, which did not prove to be proliferous; nor did the later fronds produced by the parent fern, which turned out to be a crested form of very ordinary type.

The second example (*Fig.* 2), however, has proved a constantly proliferous form, bearing two sorts of fronds belonging to the *uncum* strain, to which, by the way, Mr. Mapplebeck's plants belonged, a fact which confirms the correctness of the verbal record. One type of frond is long and narrow, but slightly crested and barren of bulbils; the others, however, are densely crested *à la acrocladon*, and the bulbils are so densely scattered among the divisions of the crests that they have, when opened out, the appearance of being peppered. If these crests be layered in the autumn a little forest of young ferns rises from the spot in the spring. This form, in its earliest stage, will be

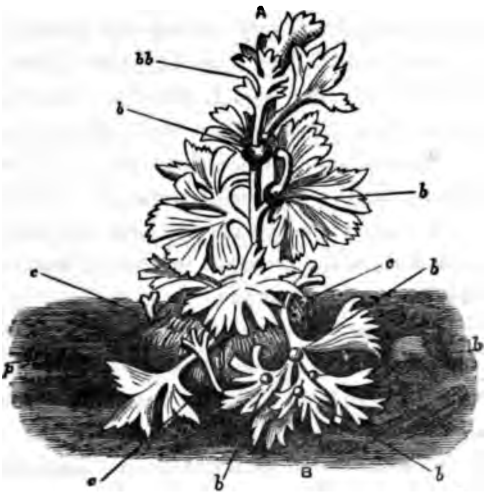


*Fig. 1.**

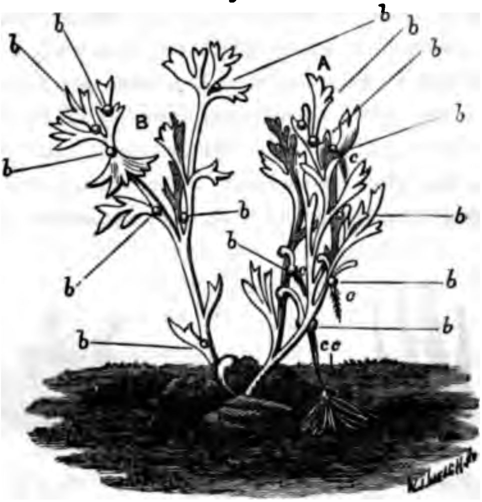


*Fig. 2.**

* Figs. 1 and 2 copied, by permission, from the *Gardeners' Chronicle* (December 16, 1882, and December 22, 1883).

seen by the figure to be a very curious one indeed. The first two fronds developed no less than 14 buds in the autumn of 1882, some of which, as in *Fig.* 1, threw out aërial roots which in one case, as figured, reached the soil. Strange to say, these two fronds persisted through the winter in my cool fernery, and in the following January resumed growth, forking dichotomously over and over again at the tips of the pinnules, and producing many more bulbils in the process. In point of fact, the two first fronds yielded a pot full of young plants.

One extraordinary feature of this proliferousness is the extreme precocity of the plants, bulbils usually being produced only on the ripe fronds of mature ferns, while these had only just emerged from the prothallus.

These two plants were exhibited at the Linnean Society in November, 1882, and six others from the same batch and of the same type developed eventually bulbils in their crests, but not to such a degree as in the first find, nor at so early a stage.

Stimulated by this discovery I pursued my researches, and in 1883 I was able to record the discovery of the proliferous character of the Athyria in another and most unexpected direction, viz., the plumose varieties. On September 18th I was examining a large specimen of *A. F.-f. plumosum divaricatum*,

*Fig. 3.**

*Fig. 4.**

* Figs. 3 and 4 copied, by permission, from the *Gardeners' Chronicle* (December, 1882 and 1883).

and was much struck by the fact that, in place of sori for which I was searching, the under surface of the pinnæ was studded profusely with minute nodules, surrounded, shuttlecock fashion, by scales. Applying a lens, I found the central excrescence to be rounded and of a brilliant green, while the scales were of a symmetrical lanceolate shape and beautifully reticulated. (*Vide Fig.* 3.)

My immediate impression was that they were bulbils, which, however, I could hardly credit, as to my knowledge no fern, British or exotic, had been known to produce bulbils on the *under* side of the fronds, and in the place of the sori. Determined, however, to try the question practically, I laid down several pinnæ, under side uppermost on sandy soil, the result being that on October 31st I was able to report to Mr. G. B. Wollaston that their bulbil character was established, since in one case a frond with three pinnae had arisen, and in many cases the circinate form had been assumed by less developed ones. In reply to this announcement, Mr. Wollaston informed me that my discovery of this form of proliferousness had been anticipated, though upon another form of Athyrium, and only a few weeks previously; since on September 6th he had seen a plant of *A. F.-f. plumosum elegans* in the possession of Mr. Carbonell, of Usk, upon which similar bulbils had just been discovered by his gardener, Mr. Cropper. Mr. Wollaston, however, added that, so far, no signs of development into plants had been visible, and that to the best of his belief I was the first to raise plants. Colonel Jones, however, on a subsequent visit reported that minute fronds had appeared, as in my case. I may add that in the following spring Mr. Wollaston, myself, and, I believe, others, had succeeded in raising plants. On pushing my enquiries further I elicited the fact that presumed bulbils had been discovered by Mr. Stewartson on another plumose form, and also many years previously by Mr. Lowe upon the Axminster

plumosum, the parent of *A. F.-f. plumosum elegans*; but that, until the autumn of 1883, their true character as bulbils had not been established, as repeated attempts had failed to do more than induce the formation of one or two fronds without roots or any apparent independent axis of growth, the said fronds dying as the parent frond lost its vitality during the winter. Mr. Moore, in his "Nature Printed Ferns," apparently makes the only allusion to this pseudo-proliferous phenomenon, as he speaks of the occasional transformation of sporangia into little bunches of leaves, which exactly describes the case as it stood anterior to 1883.

With regard to *A. F.-f. plumosum elegans*, there is a special interest attaching to the fact which I observed, that not only does it bear bulbils proper and sori proper intermingled, but also intermediate transitional stages, which I am very sanguine will throw some altogether new light upon the transformation of the sori into bulbils and the indusia into scales. With this view I have provided Prof. F. O. Bower, of whom more anon, with a portion of a frond bearing ample material for the elucidation of this problem. Prof. Bower has kindly undertaken to investigate this point by means of microscopic sections, &c., and a report thereon will, I hope, appear in the course of the year.

The next discovery, to which the foregoing ones led, was that of the singular and altogether different phenomena presented by *A. F.-f. Clarissima*, with regard to which I cannot, I think, do better than repeat to you verbatim the reports which I laid before the Linnean Society, in 1883 and 1884, and the confirmatory observations of Prof. F. O. Bower, of the Joddrell Laboratory, who received from Professor Thiselton Dyer the material which I sent him with a view to that minute and thorough investigation which only professional skill of a very high order is able to conduct.

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"The reproduction of the Filices by their spores result from sexual action taking place upon the under surface of the prothallus to which the spore gives rise. So far, I believe, no development of the perfect prothallus has been observed without the agency of the spore, and the following record of such a case therefore deserves special notice."

"Some years ago a very distinct and beautiful form of *Athyrium Filix-fœmina* was found wild by Mr. Moule in North Devon, from whose possession it passed into that of Colonel Jones, of Clifton. Many attempts were made at the time to propagate it from what were assumed to be spores, always, however, without success; and at length it was taken for granted that the peculiar growths produced by this fern in the place of sori were merely abortive spore-cases, and that the plants, like some other abnormal forms, lacked the special vigour necessary for the formation of perfect reproductive spores. All further attempts at raising it were consequently abandoned; and only two divisions of the plant exist.* In the autumn of 1883 I discovered upon another *Athyrium* (*A. F.-f.*, var. *plumosum divaricatum*) numerous proliferous bulbils occupying the place of sori on the back of the fronds; and, reporting this to Mr. G. B. Wollaston, he was led to re-examine *A. F.-f. Clarissima*, as the fern in question had been named by Colonel Jones, and came to the conclusion that these so far barren excresceuces might be viviparous growths of a kindred nature, and capable of reproducing the parent form by direct bud-development. A portion of a frond was consequently sent to me, and upon examining it under the microscope I found that there were very material structural differences between the unmistakable bulbils of *A. F.-f. divaricatum* and the singular

* It is, of course, open to question whether the excrescences formed prior to 1883 were of exactly the same nature. Colonel Jones inclines to the belief that they approached more nearly the character of sori, and did not in previous years present the same appearance as now described.

growths upon *A. F.-f. Clarissima*, the former being solitary bud-like growths seated in the centre of a number of brown lanceolate scales and without a trace of indusium (*Fig. 3*); while the latter were composed of 5 or 6 or more flask-shaped bodies, each one larger than the bulbils aforesaid, and seated within an undoubted indusium (*Fig. 4*). The masses were sufficiently large for their formation to be clearly distinguishable by the naked eye, covering more than the space of an ordinary sorus. At this stage no signs of spores or spore-cases could be detected, nor could any axis of growth be perceived; so that it was impossible to form any theory as to the eventual mode of reproduction which might result; for although the tips of the flask-shaped pseudobulbils were in some cases elongated into filiform processes, no sign of circination or resemblance to fronds was visible, added to which the presence of an indusium in the place of the scales common to true bulbils led to the assumption that they were abnormal sporoid growths, and not proliferous ones likely to produce plants by direct bud-growth."

"To test their capabilities I laid down on November 27, in a duly prepared seed-pan, numerous pinnæ, which I imbedded edgewise half way in the soil, the growths being thus brought into immediate contact with it, lying as they did along the rachides of the pinnæ. I then placed the pan in slight heat, with the result that the pseudobulbils immediately began to increase in size and to develope in such a fashion, that on December 24 I was able to record an evident foliaceous extension and division of the tips of the pseudobulbils, and the appearance of numerous long, rigid, glassy-looking rods of hairs which sprang from their bases. These rods bore a strong resemblance to the root hairs common to the under sides of prothalli; but their decided upward growth, radiating stiffly, seemed opposed to this view, as also the fact that they sprang from the bases and sides of the pseudobulbils. It is probable, however, that they acted as aerial roots, for the growth of the tips of the pseudobulbils proceeded rapidly, until, on February 10 of the present year, I recorded that they had assumed a decided prothalloid form, while the upright rods had either become deflected

or absorbed. Eventually all the tips of the flask-shaped bulbils assumed the form of perfect prothalli of the usual size and shape, the pseudobulbils themselves being absorbed and disappearing, and the usual root-hairs developing under the prothalli. On March 17 several of these prothalli were examined microscopically, both by myself and by the Rev. Mr. Aubrey, of Salisbury (to whom I am indebted for aid in observing the final stages of growth), and well-developed archegonia were found in the usual place and number, but so far neither of us was able to detect antheridia. Early in May, however, I succeeded in finding a single antheridium; and it is manifest that many others must have been present on the prothalli not examined, as on May 21 the final stage was reached, small fronds being visible in several cases, projecting from the bifurcation of the prothallus, and evidently therefore produced from the archegonia by the ordinary sexual mode of reproduction; though the prothalli, as has been shown, had developed from growths that differed widely from spores in their form, their size, persistent adherence to the pinnæ, their production of root hairs from their surface, and, finally, the development of the prothallus from their apices by simple extension of growth."

"Lest it might be assumed that these prothalli may after all have resulted from true spores scattered amongst the excrescences described, it should be borne in mind, first, that no spores or spore-cases could be distinguished when the pinnæ were laid down; secondly, that all attempts to raise this fern from spores have failed; and finally, that the entire development of the prothallus from the pointed tip of the pear-shaped pseudobulb—its dilatation, bifurcation, and gradual assumption of the true prothallus form—has been carefully watched and noted step by step, not merely in one case, but in many, in all of which the prothallus was evolved in the same way precisely."

"Where, as in this case, the whole phenomenon is new to the observer, many points of interest are apt to be overlooked, their importance being unknown until too late. Another season's growth may therefore confidently be expected to throw more light upon this development, and especially in relation to the first appearance

of the pseudobulbils themselves, which only came under close observation when already of considerable size.'"

"In framing this account of the occurrence, I have confined myself as strictly as possible to a simple and, I hope, clear record of the phenomena observed during the various stages of growth of the abnormal sporoid excrescences under observation. In conclusion, however, I may be permitted to point out, in connection with such phenomena that, so far as formal records are concerned, the family of *Athyria* has hitherto been remarkable for the nonproliferous character of the fronds, which, considering, first, its near relation to the *Asplenia*, so many of which are profusely proliferous, and, secondly, the protean nature of the family itself, is a singular fact. The discovery, however, of numerous proliferous buds which appeared upon some very small plants, which I exhibited here in 1882, led me to institute further inquiries into this subject. I then ascertained that Mr. Mapplebeck had already observed the same phenomenon, and raised plants from similar bulbils, which appeared identical in position and character with those of the *Asplenia*. Last year, as already remarked, I found another and very distinct form of proliferation on a mature plant of *A. F.-f. plumosum divaricatum*, upon which numerous bulbils were evolved in the place of the sori; this, be it observed, being on the under side of the pinnæ, a most unlikely place for such growths. This same transformation of the reproductive energy had already been observed on three other kindred forms of *Athyrium*, upon one of which bulbils and sori were scattered almost indiscriminately over the back of the fronds, some of the sori seeming to be in an intermediate amorphous condition; though in all other cases, so far as I could see, the sori and bulbils were distinctly differentiated by the presence, in the former case, of an indusium, and in the latter of lanceolate scales arranged shuttlecock fashion round the bulbils, no trace of indusium existing. Such bulbils had, until this season, failed invariably to yield plants, and seemed incapable of forming a proper axis of growth. Mr. G. B. Wollaston has, however, succeeded in obtaining plants this spring from *A. F.-f. plumosum elegans*, and one or two of those from *A. F.-f. plumosum divaricatum* have developed fresh fronds with me."

Plate VI.

Fig. 3.

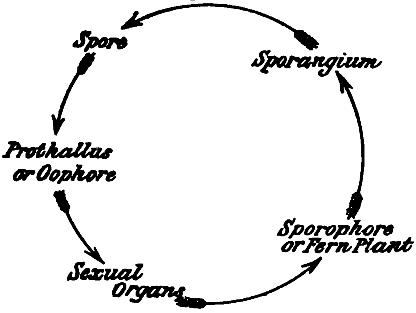


Fig. 5.

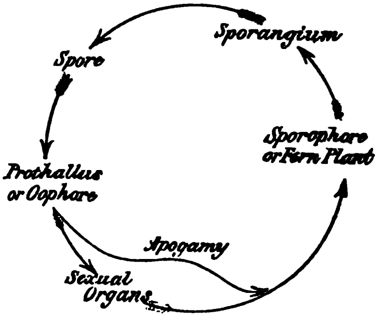


Fig. 4.

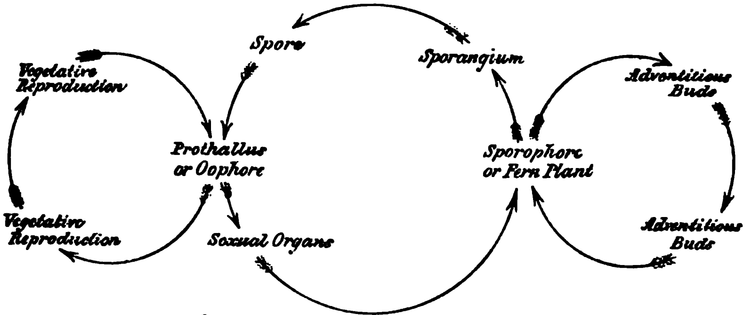


Fig. 1.

Fig. 2.

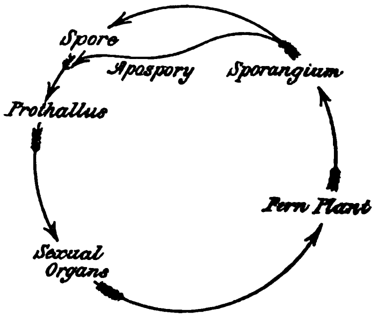


Fig. (

Fig. 7.

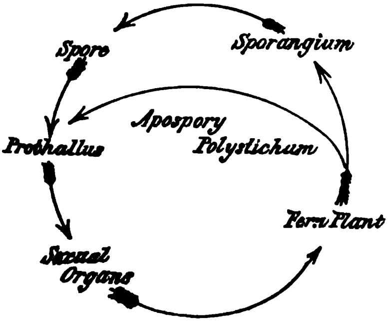
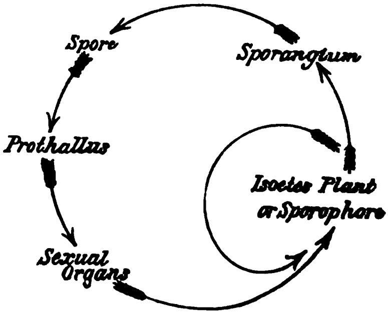


Fig. 8.



APOSPORY IN FERNS.

"From this it will be seen that no less than three distinct forms of proliferation have now been observed on the *Athyria*."

"1. Bulbils of the ordinary character developed in the axils and on the superior surface of the pinnæ, and agreeing in character with the ordinary bulbils of the *Asplenia*."

"2. Bulbils formed apparently by transmuted spore-producing energy and occupying the place of sori, *i. e.* on the under side of the pinnæ—a position so far, I believe, quite unrecorded in connection with any of the Filices."

"3. A new form of proliferation altogether, viz., proliferous prothalli arising from pseudobulbils produced by a different transmutation of the reproductive force, and evolving plants only after the prothalli have produced the usual sexual organs common to prothalli resulting from spores."

The reading of this paper aroused some little interest, but was received decidedly *cum grano salis*, especially as it was then not in my power to do more than lay my report before the Linnean Society, the resulting plants being too small to display their parentage, while the pseudobulbils and preliminary phenomena had of course successively passed away. I promised, however, that in the following autumn I would lay plants before them, and also, if possible, the curious pseudobulbils themselves. Accordingly, on Nov. 20, I did so, so far as plants were concerned; but unfortunately, as I then thought, though it turned out to be immaterial, I could only exhibit pinnae of *Clarissima* bearing very immature excrescences, owing to the plant having been more in the open air than in 1883, and the year having been a very dry one, the result being that the indusia were not even lifted, and nothing approaching the pear-shaped bodies was visible. When the indusia were raised, however, an experienced eye could detect that the bodies they covered were of a very abnormal character; and though altogether unlike the pear-shaped bodies of the previous year (*Plate VI., Fig.* 1) were

equally unlike what normal sporangia would appear at the same stage. I give an enlarged representation of one of the pseudosori (*Plate VI., Fig.* 2), by which it will be seen that they consisted of a considerable number of clavate bodies occupying the place of sporangia. I expressed my opinion that under more favourable circumstances some four or five of these bodies would have assumed predominance and become pear-shaped, the rest aborting, as in many analogous cases—an opinion which was strengthened by the fact that among the bases of the pear-shaped bodies of 1883 there were numerous thready and shrivelled bodies, which were exactly such as would result from such a process.

The outcome of this exhibition was that Dr. Murie, Professor Thiselton Dyer, and another, requested me to supply them with material for further investigation. I did so, and Professor Dyer deputed Prof. F. O. Bower to examine the matter, with the result that my observations were confirmed throughout; Prof. Bower, on December 18, giving his report, and stating that an undoubtedly new phenomenon was thereby shewn to exist, viz., the reproduction of a fern by sexual action taking place upon prothalli which had been generated without the mediation of the spore, to which phenomenon he gave the term Apospory. Prof. Bower upon that occasion demonstrated that the prothalli sprang from the stalk of the sporangia, that portion of the sporangium which would normally produce the capsule filled with spores being either entirely aborted at an early period or partially formed and then thrown off. In some cases they appeared to have exhausted their energy in endeavouring to produce spores, since in every case where they had made a distinct advance in that direction they were afterwards aborted altogether.

This singular fact throws, I think, some light upon the formation of the pear-shaped bodies of 1883, where we may assume that the extra stimulus of a specially favourable season

may have impelled most of the would-be sporangia too far in the normal direction, the result being their abortion and the monopoly of the whole of the vigour of the pseudo-sorus by a select clique of four or five of what we may consider the more conservative part of the community.

The growths of 1884 seemed most unlikely subjects for the production of prothalli and plants, but they have proved themselves, so far as prothalli are concerned, to be capable of producing them in far greater numbers than those of 1883, the large majority of the clavate bodies having, even with quite cool treatment, produced prothalli, which I have no doubt whatever will yield plants in due time.* I have brought down with me a few pinnae of *Clarissima* shewing the prothalli, and it will be observed that it is almost immaterial whether the pinnae be laid down with the excrescences uppermost or undermost, as under close culture they develop in either case, actually lifting the pinnae from the soil when developed underneath them.

It will thus be seen that the fact has been established beyond all doubt that Colonel Jones's beautiful *Athyrium* forms a new link between the ferns and the flowers, a fact of which he probably little dreamed when rescuing it as he did, literally "a brand from the burning." My thanks, and very sincere ones, are due to him, and also to Mr. Wollaston for providing me with materials and aiding me in carrying my investigations through, and getting their truth accepted and confirmed by the best authorities.

In my opening remarks I alluded to a second discovery of Apospory, for which we are indebted to Mr. G. B. Wollaston, a discovery which quite throws into the shade that in *A. F.-f. Clarissima*, the prothalli in this case (*Polystichum angulare*, var. *pulcherrimum*, Padley) being actually produced altogether independently of the sori, without even a local connection,

* June, 1885. They did so in profusion.—*C. T. D.*

springing, as they do, from the extreme tips of the pinnae. So far, although antheridia and archegonia have been observed on these prothalli, and their true nature is thus beyond a question, the process of reproduction has not been completed; plants have not resulted. The case, however, constitutes not merely a second one of Apospory, but also a new form of the phenomenon.

To Prof. Bower I am indebted for illustrations of the life cycles, normal and abnormal, of the Filices, including the two forms of Apospory (*vide Plate VI.*), of which illustrations I give an enlarged view upon the diagram before you. The normal cycle (*Fig.* 3) consists, as already stated, firstly, of the spore-bearing fern or sporophore, then the sporangium, spore, prothallus, the sexual organs thereon, and finally the reproduction of the sporophore. This normal cycle is, however, both lengthened and shortened by abnormal methods of reproduction; thus it may be lengthened by the parent fern producing young plants by adventitious budding on the upper surface of the frond, a faculty which the prothallus occasionally also possesses, viz., of producing other prothalli by vegetative reproduction, the one spore thus yielding numerous plants of the sporophore generation (*vide Fig.* 4, *for both phenomena*). On the other hand, the cycle may be shortened by the prothallus yielding plants of the sporophore generation by direct budding without sexual action, *i.e.*, Apogamy (*Fig.* 5), or by Apospory, where, in the case of *A. F.-f. Clarissima*, the spore is missing from the cycle; the stalk of the sporangium producing the prothallus (*Fig.* 6); while in the other case of the Polystichum, not merely the spore but the sporangium also is excised, the prothallus springing directly from the frond of the sporophore (*Fig.* 7). The further illustration (*Fig.* 8) relates to one of the fern allies (Isoetes lacustris), but is exactly paralleled in the fern family by the buds I have already described as formed in the place of sori, *i.e.*, on the *under* surface of the frond in the plumose Athyria.

In conclusion, while thanking you for the patient hearing which you have accorded to what I fear has been to some of you a rather dry subject, I would ask those gentlemen present who take a special and active interest in our beautiful native ferns to examine their plants anew, and with special care, with the object of discovering, if possible, other cases of Apospory, or perhaps new phenomena of a kindred nature. Bearing in mind the wonderful capacity for variation in the most unexpected directions which our British ferns possess, whether under cultivation or in their natural state, and the singular fact that Nature, left to herself, supplies the most marked departures from the normal forms, *A. F.-f. Victoriae* and *Acrocladon*, for instance, among the hardy ferns; bearing, I say, these facts in mind, it is singular that so far little attention has been paid to them by professedly scientific men, the fact of their variability seeming rather to earn for them the contempt of botanists, who do not scruple to call them mere monstrosities.

Now, my belief has long been that this faculty of variation affords a rich field of research for morphologists, amateur or scientific, a belief which I need hardly say has been quite confirmed by the discoveries which I have had the honour of laying before you this evening. To render research, however, profitable, it is essential that when unusual phenomena are remarked they should be at once investigated as thoroughly as possible, and, their true nature being established, that some permanent record be made of the fact. Each new fact becomes thereby a stepping-stone for further research, and general science is so much the richer; while without this, the discovery is apt to die with the discoverer, or, at the best, become mere hearsay, confined to the knowledge of a few, and rarely forming a reliable basis for additional data.

Rainfall at Clifton in 1884.

By GEORGE F. BURDER, F. R. Met. Soc.

TABLE OF RAINFALL.

	1884.	Average of 30 Years.	Departure from Average.	Greatest fall in 24 Hours. Depth.	Greatest fall in 24 Hours. Date.	Number of days on which ·01 in. or more fell.
	Inches.	Inches.	Inches.	Inches.		
January ...	4·820	3·251	+1·569	0·738	26th	20
February ...	1·849	2·318	−0·469	0·291	23rd	18
March	2·689	2·216	+0·473	0·985	3rd	15
April	1·117	2·144	−1·027	0·340	4th	11
May	2·501	2·362	+0·139	0·733	2nd	12
June	3·867	2·623	+1·244	2·440	28th	9
July	3·665	2·959	+0·706	0·922	23rd	19
August ...	2·744	3·595	−0·851	0·692	30th	12
September ...	1·998	3·355	−1·357	0·328	1st	19
October ...	1·167	3·793	−2·626	0·342	8th	7
November ...	1·686	2·856	−1·170	0·407	2nd	13
December ...	5·289	2·841	+2·448	1·165	5th	18
Year	33·392	34·313	−0·921	2·440	June 28th	173

Remarks.—The total rainfall of the year differs but little from the average of 30 years, showing a deficiency of something less than one inch. Six months were in excess of the average, and six were in defect. The rainy months were mostly in the first half of the year, and the dry months mostly in the latter half, with the result that the entire fall of the first half of the year exceeded the entire fall of the second half—a noteworthy deviation from the ordinary rule. From August to November the deficiency was continuous and very marked. The fall in October was the smallest recorded here in that month during a period of 32 years, and the aggregate fall of the four months was also the smallest recorded here in the same four months. Nevertheless, no general inconvenience was experienced in these parts, the normal rainfall of those months being sufficient to allow of a large reduction without any approach to absolute drought. In some of the northern towns the scarcity of water was at one time becoming serious.

The rain in December largely exceeded the average, amounting to 5·289 inches, and the whole of this quantity fell in the first 19 days of the month, the last 12 days being rainless. December was the wettest month of the year, and April was the driest.

A remarkably heavy downpour occurred in the night of the 28th of June, when 2·44 inches fell within ten and a half hours. On the fifth of December also the fall exceeded an inch.

The year was almost free from snow, no greater depth than half an inch having been registered.

Meteorological Observations, as regards Temperature, taken at Clifton, 1884.

By H. B. JUPP, M.A., F. R. Met. Soc.

THE observations from which the following tables are derived have been taken at 8.30 a.m. daily. The Thermometers used, with the exception of that for the Ground Temperature, are kept in a Stevenson cage; and in all the readings the requirements of the Royal Meteorological Society are strictly complied with.

1884 TEMPERATURES.

MONTH.	Maximum in Shade.		Minimum in Shade.		Mean in Shade.	Minimum on Ground, Lowest recorded.
	Highest recorded.	Mean.	Lowest recorded.	Mean.		
January ...	54·4	48·0	29·1	40·3	44·17	29·1
February ...	53·6	46·5	28·8	38·1	42·30	27·8
March ...	68·1	51·2	30·9	38·6	44·90	28·1
April	57·7	52·1	30·8	37·9	45·01	25·1
May	80·1	62·9	38·9	43·8	53·35	36·2
June	80·1	69·0	42·0	50·7	59·85	37·7
July	75·5	69·2	48·0	52·3	60·73	45·7
August ...	87·5	73·3	47·5	55·7	64·50	44·8
September ..	76·3	65·9	42·1	53·0	59·44	38·6
October ...	62·8	55·2	30·8	42·6	48·90	30·3
November ..	57·8	46·6	22·6	36·6	41·60	23·7
December ...	54·9	47·0	32·0	39·3	43·15	27·2
Year 1884...	87·5	57·44	22·6	44·07	50·66	23·7
Year 1883...	82·5	54·54	20·9	42·88	48·71	19·3
Year 1882...	78·5	55·46	21·9	43·62	49·54	20·6
Year 1881...	86·9	55·44	12·3	42·92	49·18	5·8

[redacted]

MONTH.	Number of Days on which the Minimum Ground Temperature was below 32°	Number of Days on which the Minimum Air Temp-rature was below 32°.	Number of Days on which the Maximum Air Temperature was below 32°.	Number of Days on which the Mean Air Temperature was below 32°.	Humidity in percentage of Saturation. Mean of Values at 8.30 a.m.
January ...	4	3	0	0	90
February ...	4	2	0	0	84
March ...	10	2	0	0	82
April	11	2	0	0	79
May	0	0	0	0	78
June	0	0	0	0	72
July	0	0	0	0	75
August ...	0	0	0	0	75
September...	0	0	0	0	87
October ...	4	2	0	0	85
November ..	12	8	0	1	90
December...	6	0	0	0	89
Year 1884...	51	19	0	1	82·2
Year 1883...	79	40	0	6	82·8
Year 1882...	63	26	2	7	—
Year 1881...	94	60	11	24	—

The year 1884 was warmer on the average than any one of the three years that preceded it. The only month in which the mean shade temperature fell below the average was April. The number of frosty nights and days was also far below the average of these three years.

The Heart-beat.

Abstract of Paper

By G. MUNRO SMITH, L.R.C.P.Lond., M.R.C.S.

WHEN the hand is firmly pressed against the left side of the chest, we can readily feel the rhythmical thumping sensation due to the movements of the heart beneath the ribs. These movements, which in thin people can be seen as well as felt, occur, in health, with perfect regularity, and are the outward sign of that enormous though unobtrusive work on which our very existence depends.

The heart is a strong, hollow, muscular cone, divided into four cavities, which communicate with each other and with the whole circulatory apparatus of the body. Every time it "beats," or contracts, it squeezes the blood into the arteries with sufficient energy to make it travel at the rate of one foot per second. As the tubes into which it flows become ultimately extremely minute, there is great resistance to the onward stream, and a corresponding force is necessary in the central pump. For instance, each contraction squeezes out from nine to twelve ounces of blood, and does enough work to lift a weight of three pounds to a height of three feet. As this occurs sixty times a minute at least, we can calculate that in 24 hours this small engine does work equivalent to raising 124 tons to a height of 124 feet. The heart of old Sir Moses Montefiori, whose hundredth birthday was celebrated a few months ago, must have beaten more than 5000 millions of times, and manifested enough energy to raise five millions of tons to a

height of eight or nine hundreds of miles. Yet all this is done so smoothly and harmoniously that we are not generally conscious even of the existence of such an organ. By applying to the chest wall an instrument called a cardiograph we can magnify these movements, and by suitable apparatus obtain a record of each contraction written by the heart itself. By listening with a "stethoscope" we can hear the sounds made by the blood being driven through its chambers or stopped by its membranous valves, for, like other pumps, it is so constructed that fluid can travel through it in one direction only. In some simple organisms there are no valves. The heart in these is a mere muscular tube connected at either end with blood vessels, and the fluid travels first in one direction for a certain number of beats, and is then reversed and forced in the other. This can be easily seen; and in cold-blooded animals, such as frogs and turtles, the heart will continue to beat for hours or even days after its removal from the body, provided it be kept moist.

By these and other methods of investigation a vast amount of knowledge has been gained as to the mechanism of the cardiac movements, and much light has been thrown on that most interesting question: "*Why* does the heart beat?" Like most problems in physiology, when pushed far enough, this baffles our endeavours. Dr. Brown-Sequard says that it is the presence of impure blood that stimulates its muscular fibres to contraction. Others say that it is the mere contact of fluid. Yet the heart will beat when empty, so this hypothesis does not hold.

Then there is the commonly-received theory that the nerves scattered throughout the heart-substance, and those connecting it with the brain, are the cause of its movements. Undoubtedly they are to some extent, but not altogether, for the developing heart beats before it contains either nerve or muscle. Dr. Carpenter says:—"The essential cause of the rhythmical contraction of the heart must still remain an unsolved question."

The explanation I am going to suggest will seem to some no explanation at all. It is this: that the heart beats because it inherits the power of beating; that as an animal transmits to its offspring its form and instincts, so it hands down this power of rhythmical contraction of the heart. It is a question of inheritance. We inherit a limited life, and a heart whose power is also limited. Nay, more; the heart of an animal always begins to beat at the same time as its parent's did before it. If you put a hen's egg into a warm, uniform temperature for a couple of days and then carefully chip off the shell, you will see, lying upon the yolk, a small, red, palpitating spot, which is the future heart. I say *future*, because as yet the heart is merely a mass of cells, hollowed out in the centre, and has neither muscle nor nerve in its walls. Yet it beats regularly and always begins at about the same time—towards the end of the second day of incubation—because its father's did before it. This great principle of inheritance, the most important law in the organic world, is no mean explanation of the heart-beat, although at first it seems ridiculously simple. How that movement originated ages ago we are not concerned with now.

The reason of the *regular rhythm* of the heart-beat is also unknown; but we notice, as Dr. Michael Foster has observed, that rhythm is the order of the Universe. The moon and the earth and other planets have stated intervals in which to revolve; our brains have alternately periods of rest and activity; the lives of men and all other animals have fixed durations, beyond which they cannot go. They gather strength, beat, and cease, as the heart gathers strength, contracts, and lies quiet until the next pulsation. "The heart," says Foster, "is the reflex, in little, of the cycles of the Universe."

Reports of Meetings.

GENERAL.

DURING the past Session there have been nine meetings of the Society—eight ordinary and one special—all held in University College.

The first was on Thursday, October 9th, when Mr. Thomas Morgans, C.E., gave an account of the manufacture of paper from wood. Poplar, spruce, or some other wood, comparatively free from resinous material, is chopped up by powerful machinery, and then boiled at high pressure for four or five hours with a solution of caustic soda, or with sulphite of lime or magnesia. The result is a pulp similar to that used in ordinary paper works; and the subsequent processes of manufacture are those usually followed. Good specimens of the paper were exhibited, and also a small casting in wood-pulp board. Dr. Burder then made an interesting communication on the "Recent Eclipse of the Moon," which will be found on page 166.

On November 6th, Mr. G. Munro Smith read a paper on the "Heart-beat," an abstract of which is printed at page 234. Prof. Ramsay, Ph.D., subsequently gave a vivid description of "The Volcanic Phenomena in the United States National Park on the Yellowstone River," as observed by him during a recent visit.

On December 4th, Mr. W. A. Shenstone, F.C.S., gave an account of "The Physiological and Chemical Work of Jean Baptiste André Dumas," illustrated by a large number of his original experiments, and by models of his appliances.

On January 8th, 1885, Mr. William Hancock, F.L.S., F.R.G.S., read a paper on "The Volcanoes of Central America, with an account of the recent active phenomena observed in that region." He alluded to the old and incorrect definition of a volcano as "a burning mountain shooting forth smoke and flame." A volcano was a hole in the outer crust of the earth, by means of which a communication existed between the heated interior and the surface; and through which, from time to time, steam, gases, scoriæ, and molten rock, or lava, were ejected. It must not be imagined, however, that the rocks of the interior of the earth were necessarily in a molten condition. Physicists rather inclined to the opinion that the interior of the earth was solid, though kept so only by the enormous superincumbent pressure, on the diminution of which the rock assumed the molten form. The fact has been established that water is an important, if not indispensable, agent in volcanic eruption. Relief of pressure causes the water, held in a liquid condition within the rocks, to flash into steam, and give rise to paroxysmal, or continuous, eruptions. Variations in barometric pressure may in some cases determine a volcanic eruption. At Stromboli a variation of 2 inches of mercurial pressure has been noted in a short space of time; and that would mean an increase or decrease of two million tons pressure per square mile. After describing the steam geysers in Formosa, in the tubes of which he had seen molten sulphur, the condition of which made possible an estimate of the temperature, Mr. Hancock gave a full and interesting account of the volcanic phenomena he had observed in many parts of Central America. One of the most striking facts was that relating to a line of three volcanoes named Pacaya, Agua, and Fuego, of which that in the median position had never, within historic times, been known to be in eruption, though the other two had frequently been active. The volcano of Izalco resembled Stromboli in being continuous in its action;

though periods of quiescence, followed by eruptions approaching the paroxysmal type, had been known to last for two years. It had existed since 1798, and had now reached the height of 2500 feet. An eruption occurred on an average every 13 minutes. A specially interesting account, also, was given of the earthquake phenomena in San Salvador, and the formation of a new volcanic cone in a neighbouring lake.

At the meeting on February 5th, Mr. Edward Wethered, F.G.S., F.C.S., described some original researches on the structure and formation of coal. He advocated, with Prof. Huxley, the microscopical examination of sections cut from the coal at various depths, as the best method of investigating the nature of its formation; and gave as his opinion that the plants from which coal was formed were more closely allied to the *aquatic*, than to the *terrestrial*, Lycopods.* Prof. S. P. Thompson, D.Sc., then exhibited and described some scientific appliances for the rapid extinction of fire. One was the "Automatic Sprinkler," an arrangement by which, if the temperature of a room rises much above a summer heat, a large number of jets of water are liberated by the melting of a fusible alloy. In America, where factories are commonly fitted with this appliance, a great many fires have thus been automatically extinguished by the action of their own temperature. Another appliance described by Prof. Thompson was the "Harden Hand Grenade," which, when thrown into the fire, bursts, and liberates large quantities of steam or other vapours, which prevent further combustion.

A special general meeting was called on February 21st, to receive a communication from Mr. Charles Druery, F.L.S., of London, on "The Aposporous Production of Prothalli of Ferns." To this meeting members of the Bristol Microscopical Society,

* This paper is printed in full in the *Journal of the Royal Microscopical Society*, Series 2, Vol. 5, Part 3.

and others interested in the subject, were invited. This paper will be found on page 211.

On March 5th, Mr. J. G. Grenfell, F.G.S., gave an account of a stay of six weeks which he had made at Port Royal, Jamaica. He described the situation of the place, and gave an account of the different kinds of fish which are met with in the harbour, and the methods of catching them. These included the devil-fish, sharks, king-fish, bonitos, jack (cavaux), the remora, flying gurnards, diodon, tetraodon, cestracion, and others. He also gave an account of the many kinds of crabs found on the shore, and of the butterflies found on the island. Numerous specimens were exhibited.

On Tuesday, March 31st, Prof. Ramsay, Ph.D., gave a lucid description, illustrated by numerous experiments, of the researches by Prof. Lodge and Mr. Aitken (of the Royal Society of Edinburgh), which showed conclusively the part played by dust particles in serving as nuclei on which fog may form, and that the absence of dust from the air renders the formation of fog impossible. Much interest was excited, and an animated discussion followed; after which Mr. S. H. Swayne read an account, by Mr. Edward Wilson, of the whale recently stranded in the Severn. This account will be found at page 204.

The 23rd annual meeting of the Society took place on May 7th. After the transaction of the usual business, Prof. Lloyd Morgan, F.G.S., read a paper of especial local interest, entitled "Sub-aerial Denudation and the Avon Gorge." This is printed at page 171. Mr. Alfred E. Hudd then mentioned the recent occurrence in the neighbourhood of Bristol of a rather rare bird, the "Pied Fly-catcher" *(Muscicapa atricapilla)*. "In Mr. Edwin Wheeler's list of the birds observed in the Bristol district which was published in our Proceedings for 1875 (New Series, Vol. I., page 366), this species is described as 'a rare summer visitor'; the only one recorded from the district at that time having been

observed near Long Ashton many years before. In 'Winscombe Sketches' (page 114) Mr. Theodore Compton writes:—'The Pied Fly-catcher is a very rare visitor in this county. It has been shot near Taunton; and about 12 years ago (*i. e.*, 1870) a pair built in a wall plum-tree in Mr. Clothier's garden, near Street. Being a true bird-lover, he gave strict orders that the birds should be protected, and he had the pleasure of seeing them bring out their brood.' The species does not appear to have been hitherto recorded from Gloucestershire. Our recent visitor was first observed on April 25th, while flying over a stream near Henbury, by Mr. Alfred C. Pass and Prof. Lloyd Morgan. The next day, a little further up the stream, Mr. Pass and Mr. Hudd watched for some time the pretty movements of the same bird—a male—while engaged in chasing his prey. From the branch of a willow, overhanging the stream, he darted on the flies as they passed beneath, returning after each capture to his post of observation. The females are said to arrive in this country some days after the males, so it was arranged to pay frequent visits to the spot for the next few days; and on the 27th Prof. Lloyd Morgan was fortunate in finding that the first visitor had been joined by his mate; the female being rather less brightly coloured than the male. It was now hoped they would build, and rear their young in the neighbourhood; but, though repeated visits were made to the locality, no more was seen of them. They had probably, after meeting *by appointment* at the trysting-place, where they were fortunately observed, continued their flight to the hills of Yorkshire or Westmoreland, where they are much more frequently met with than in the South and West of England. They are sometimes found near the coast, where they alight to rest before resuming the journey northward, but seldom stop to nestle there."

ARTHUR B. PROWSE, *Hon. Reporting Sec.*

BOTANICAL SECTION.

THE members of the Section have continued the customary excursions on Saturday afternoons during the summer, in accordance with a published programme.

On Thursday evening, April 30th, 1885, the annual meeting of the Section was held in University College, and the president, Prof. Leipner, communicated some notes on fresh-water algæ.

Five new species of flowering plants have been added to the local Flora during the past year; and the Secretary has collected much information for the work now in course of publication.

Part V. of the "Flora of the Bristol Coal-field" does not contain the whole of the Monocotyledones, the Glumiferæ having been reserved for another year.

J. W. WHITE, *Hon. Sec.*

CHEMICAL AND PHYSICAL SECTION.

THE Section has met regularly during the winter months, and papers have been read by Prof. Ramsay and Mr. Cundall, Prof. Thompson, Prof. Shaw, and by Messrs. Berry and Shenstone.

On May 9th, the London Physical Society visited Bristol, at the invitation of the Presidents of our Society and of the Section. The arrangements for this visit were carried out by a committee appointed by the Section, in accordance with a resolution passed by the Society at one of their meetings in 1884.

W. A. SHENSTONE, *Hon. Sec.*

ENTOMOLOGICAL SECTION.

DURING the year only one out-door excursion was taken by the Section. Wotton-under-Edge was visited in June, and a large number of species were taken.

At the in-door meetings of the Section no papers of importance have been read, but a very large number of specimens of different orders, both British and foreign, have been exhibited, including many rare and interesting species.

GEORGE HARDING, *Hon. Sec.*

GEOLOGICAL SECTION.

ON May 10th, 1884, an excursion was made to Banwell, when the bone cave and also the deep cave were examined. In the latter is a remarkable deposit or incrustation of sulphate of baryta, which appears, hitherto, to have been unnoticed; probably having been mistaken for stalagmitic carbonate of lime.

At Whitsuntide an excursion, extending over four days, was taken to the neighbourhood of Bournemouth and Christchurch. The coast was examined, and the Barton clay beds yielded a large number of fossils. This excursion, from Saturday to Tuesday, proved very satisfactory to all who joined it.

On September 10th, by invitation of Mr. Charles Richardson, C.E., an excursion was made to New Passage, to examine the tunnel cutting on the South Wales Union Railway. The ancient river-bed of the Severn, consisting of a great deposit of gravel, and also the overlying deposit of alluvium and peat con-

taining trees, were carefully pointed out by Mr. Richardson and Mr. Jones.

On November 26th a meeting was held at University College, to hear a paper by the president—Prof. Lloyd Morgan—on the carboniferous limestone at Long Ashton.

A. C. PASS, *Hon. Sec.*

[redacted]

FLORA OF THE BRISTOL COAL-FIELD.

ADDITIONS TO PARTS I., II., AND III.

Cardamine impatiens, L. in Somerset. Cheddar, sparingly among rocks in the gorge; *Miss Livett!* Near Whatley, *Dr. Parsons.* Prior Park and Lyncombe; *Add. Fl. Bathon.* See pp. 16, 85.

(*Gypsophila paniculata*, L. Casual. On the old colliery *débris* near Kingswood, G., so often referred to on preceding pages. Sept., 1884.)

128.* Alsine tenuifolia, *Wahl.*

Can take an undoubted position in the Bristol Flora. In June, 1884, Mr. H. Fisher brought us a tiny specimen from Penpole Point, G. On subsequent examination of the place the plant was found in fair quantity and well distributed on the limestone promontory, where, during so many years, it had contrived to elude observation. See p. 30.

130.* Arenaria leptoclados, *Guss.*

S. About Clevedon in several places. Mr. D. Fry has been able quite satisfactorily to separate this from typical *sphærocarpa.* The latter, however, is the prevailing form.

Cerastium pumilum, Curt. We have now a good series of stations for this plant in N. Somerset. It grows at Clevedon on the Court and Strawberry Hills, and

elsewhere. Also on rocky waste ground on the hill at Weston-super-Mare. In abundance on the S.W. slope of Brean Down. On walls near the Mineries towards Wells; and on walls between Black Down and Cheddar. See p. 32.

Cerastium tetrandrum, Curt. Is plentiful on the sands near Burnham, S. See p. 32.

274.* Rubus rosaceus, *Weihe.*

Worle Hill, S.! *Mr. D. Fry.* Confirmed by Mr. J. G. Baker, who says that this bramble is also abundant at Wyck Rocks, G.

299.* Pyrus scandica, *Bab.* *P. latifolia*, Pers?

On p. 67 we mentioned a variety of *Pyrus Aria* which formerly had been known in Leigh Woods, but which we had been unable to rediscover; nor could we find any specimen. We could not therefore assign it a place in the Flora. However, in June, 1885, we were so fortunate as not only to see specimens gathered by Mr. T. B. Flower, but also, a few days afterwards, to come across the large tree from which they had been taken. This, the solitary representative of the species in North Somerset, grows on the rocky verge of Nightingale Valley.

301* Peplis Portula, *L.*

S. On the borders of marshy pools on Mendip, not far from the Mineries; Aug. 20, 1884.

(*Xanthium spinosum*, L. Nine or ten plants on dredgings from the bed of the Avon deposited in the Black Rock quarry; flowering in October and November, 1884.)

(*Solanum rostratum*, L. Casual. On old colliery *débris* near Kingswood, G.)

Scutellaria minor, L. Additional stations in N. Somerset. Boggy and peaty ground on Mendip, four or five miles north of Wells, scattered over a large area. Aug. 20, 1884. Sparingly in a damp wood near Abbot's Leigh, half a mile from the published locality, where, this season (1885), we have noticed an increased quantity of the plant. See p. 139.

FLORA

OF THE

BRISTOL COAL-FIELD.

EDITED (FOR THE BRISTOL NATURALISTS' SOCIETY) BY

JAMES WALTER WHITE,

Hon. Secretary of the Botanical Section.

"*Rerum cognoscere causas.*"—VIRGIL.

PART V.

DICTYOGENÆ, ET FLORIDÆ.

BRISTOL:
JAMES FAWN & SON.

PRINTED BY E. AUSTIN & SON, CHRONICLE OFFICE, CLIFTON.

MDCCLXXXV.

PHANEROGAMIA.

Class 2. *MONOCOTYLEDONES:*
Div. 1. *DICTYOGENÆ.*

TRILLIACEÆ.

PARIS, *Linn.*

724. P. quadrifolia, *L. Herb Paris.*

Native; in woods, rather common. Plants bearing five, and even six leaves are often met with.

G. Berwick Wood. Bean Wood, Chipping Sodbury, *Rev. E. Johnson.* Woods between Charfield and Tortworth. Stapleton.

S. Leigh Wood, rare. Stockwood. In many woods near Bath. Maes Knoll. Norton Malreward. Plentiful in Paul Wood between Temple Cloud and Clutton; and in a wood at Rush Hill, near Farrington Gurney. East Harptree Combe. Scattered all over a small copse on Mendip, near Sidcot. King's Wood, Yatton. Portbury. Portishead. Weston-in-Gordano. Abundant in woods about Wells. Abundant in woods from Binegar to Asham. *Rev. R. Murray.* IV. V.

DIOSCOREACEÆ.

TAMUS, *Linn.*

725. T. communis, *L. Black Bryony.*

Native; in hedges and thickets, frequent.

G. Almondsbury. Charlton. Filton. Patchway. Stapleton. Westbury-on-Trym.

S. Abbot's Leigh. Leigh Wood. Bishport. Chew Magna. Englishcombe. Combe Hay. Long Ashton. Dundry. Upper Knowle. Portbury. Wraxall. Frequent about Clevedon, Weston-super-Mare, and Wells. V. VI.

Div. 2. *FLORIDÆ.*

HYDROCHARIDACEÆ.

HYDROCHARIS, *Linn.*

726. **H. Morsus-ranæ,** *L.* *Frog-bit.*

Native; in peaty ditches of the lowlands, locally common.

G. Awkley, *Herb. Powell.* Shirehampton marshes.

S. Near Clevedon. Nailsea Moor. Tickenham. Yatton. Weston-super-Mare. Marsh ditches throughout the Cheddar Valley, as far as the southern limit of the district. VII. VIII.

ANACHARIS, *Rich.*

727. **A. Alsinastrum,** *Bab.* *Elodia canadensis,* Mich.

Now naturalized with us, as in many other parts of the country; and to be met with frequently in ponds and streams in both counties. VII. VIII.

ORCHIDACEÆ.

ORCHIS, *Linn.*

728. **O. Morio,** *L.* *Green-winged Orchis.*

Native; in meadows and pastures. Common and widely distributed. It is often very abundant in cowslip meadows, where the blossom contrasts pleasantly with its neighbours. We have observed many spikes of pure white flowers in fields near Hallen, G., and also at Failand and Compton Martin, S., as well as all the intermediate shades, from pale rose to purple. V. VI.

729. **O. mascula,** *L.* *Early purple Orchis.*

Native; abundant in woods and pastures throughout the district. White-flowered plants grow in a meadow near Henbury, G. V.

730. **O. ustulata,** *L.*

Native; in elevated pasture land on limestone. Very rare.

G. "On Wick Cliffs, Mr. Swayne." *Bot. Guide.*

S. "Worle Hill, near Weston-super-Mare, May 16, 1838." *Herb. Powell.* Pastures near Weston-super-Mare, *St. Brody, Fl.* Claverton Down, *Mr. T. B. Flower.* Weston-in-Gordano, *Rev. G. W. Braikenridge;* and *Mr. T. B. Flower* in 1850. V.

731. **O. maculata,** *L.*

Native; in damp woods and meadows, common and generally distributed. V. VI.

732. **O. latifolia,** *L.* *Marsh Orchis.*

Native; in marshes and moist, peaty meadows, frequent.

G. Alveston. Aust. Filton Meads. Patchway. Siston. Abundant in meadows near Thornbury. Yate.

S. Between Abbot's Leigh and the Tan-pits. Meadows under Dundry Hill. Compton Martin. Nailsea. Bogs and peaty meadows near Winscombe. Yatton. Wells. V. VI.

733. **O. incarnata,** *L.*

Native; in boggy pastures, local. Like many other botanists, we were for a long time unable to feel sure of this species; but we have been led to the conclusion that, at the stations mentioned below, the plants are *incarnata* and not *latifolia.* They agree entirely with the former as regards leaf-characters, which seem to be the only tangible ones whereby the two species can be separated. Babington's remark on the time of flowering is also confirmatory of these plants being *O. incarnata.*

G. Hallen marshes. Compton Greenfield. Near Filton.

S. Boggy meadows between Dundry Hill and Barrow Gurney. Boggy spots in the lowlands near Burnham, and in the Cheddar Valley. VI.

734. O. pyramidalis, *L.*

Native; on banks, downs, and dry bushy places, chiefly on limestone; rather local, but abundant in many places.

G. Formerly frequent in the Avon gorge below Bristol; now destroyed or nearly so. Blaise Castle, and Kingsweston Hill. Railway banks near Horfield, and at Patchway. Plentiful on the hills above Wotton-under-Edge, Nibley, and Dursley. Wyck Rocks. Stapleton, 1842. *Herb. Stephens.*

S. Brean Down. Hilly pastures near Clevedon, and above Congresbury. Rocky hills about Combe Hay, and not uncommon in the vicinity of Bath. Between Buckland Dinham and Great Elm. On banks on both sides of the high road between Pensford and Whitchurch. On the high ground above Wraxall. Above Tickenham. Uphill. Abundant about Wells. Weston-in-Gordano. Worle Hill. VII.

GYMNADENIA, *R. Br.*

735. G. conopsea, *R. Br.*

Native; in boggy meadows and in hilly pastures, frequent.

G. Alveston. Filton Meads, plentiful in some seasons. Oldland. Pucklechurch. Wickwar. Near Wyck Rocks.

S. Meadows near Clevedon. Hutton. Weston-in-Gordano. Between Buckland and Great Elm. On Mendip at Tining's Farm, sparingly. Pasture N.W. of Dundry Hill. Several stations near Bath. Moors near Wells. VI. VII.

HABENARIA, *R. Br.*

736. H. viridis, *R. Br.* *Frog Orchis.*

Native; in meadows and hilly pastures, rather rare, and does not often occur in quantity.

G. Alveston, *Herb. Powell.* Filton Meads. Between Henbury and Patchway. Nailsworth. Pasture above Wotton-under-Edge.

S. In several fields between the Bridgwater road and Dundry Hill. Hutton. Mells. Portbury. Pastures on Mendip, near Cheddar. Near Bath; *Fl. Bathon.* VI. VII.

737. H. bifolia, *R. Br.* *Lesser Butterfly Orchis.*

Native; in moist open places, rare. Nearly all the records purporting to relate to the distribution of this Orchid in the Bristol district have been found to refer to *H. chlorantha.* *Eu-bifolia* undoubtedly grows on the southern peat moor, and in several localities nearer Bristol, one of which is that happy hunting ground for botanists—Filton Meads.

738. H. chlorantha, *Bab.* *Greater Butterfly Orchis.*

Native; in woods and shady places, frequent.

G. Rarely on the wooded slope under Clifton Down beyond the Great Quarry. Wood near Filton. Duchess Woods, Stapleton. Woods above Wotton-under-Edge. Abundant in woods near Patchway.

S. Leigh Wood in several places, but always very sparingly; usually one plant only is to be seen on each occasion. Bishport. Buckland Dinham. Chewton Keynsham. Congresbury. Shutshelf Wood near Axbridge. Ebbor. Great Elm. Hutton. Limeridge Wood near Tickenham. Stockwood. Nightingale Valley, Weston-in-Gordano. Wells. Yatton. V. VI.

OPHRYS, *Linn.*

739. O. apifera, *Huds.* *Bee Orchis.*

Native; on downs, banks, and in rough pastures, and stony places; chiefly on limestone and oolite. Rather common, and in some years very plentiful. We have seen a striking variety of this species, of which only four specimens were found on the Leigh side of the Avon in July, 1885. In all the flowers on the spike, the labellum, viewed in front, instead of being broadly oval or semiglobose, presented a long triangular outline four times as long as broad, tapering from the base to the normal long reflexed point of the terminal lobe.

G. There are many old records for St. Vincent's Rocks, and for Clifton and Durdham Downs, where formerly the Bee Orchis may have been very abundant. As might be expected, it is now almost eradicated; although in most seasons half a dozen plants are still to be seen by those who know where to look. Bank of Avon below Bristol. Cromhall. Henbury. Kingsweston Down.

S. Bank of Avon about the Portishead Railway, and on the slopes under Leigh Woods. Scattered all over a rough pasture near Failand Inn. Failand Hill. Hills near Clevedon. Elevated grassy banks near Congresbury, where four or five hundred plants have been seen blooming together. Brean Down, in plenty 1885. Cheddar. Sandford. Tickenham. Yatton. Portishead. Clevedon road-side near Wraxall. Frequent about Dunkerton, Englishcombe, Combe Hay, and elsewhere towards Bath. "Abundant among the sand-hills at Burnham, *J. C. Collins.*" *New Bot. G.* Still there, 1885. Marshy sands near Berrow. Ebbor. Easton. Lyat, near Wells. Whitchurch. About Buckland Dinham and

Great Elm. *Dr. H. F. Parsons.* Uphill, in great profusion, 1885. VI. VII.

740. **O. muscifera,** *Huds.* *Fly Orchis.*

Native; in woods, on bushy banks, and occasionally on downs, rare, but well distributed.

G. Many old writers agree in stating that this Ophrys used to grow with the Bee Orchis on St. Vincent's Rocks and on Clifton Down; and that it was at one time even more plentiful than the latter. Towards the end of the last century "the high ground at the back of the Old Well House" was especially singled out as a favourite station for the Fly Orchis. It is unnecessary to dwell upon the circumstances which have long ago unfitted this locality for the growth of Orchids. But still we believe that even now, in spite of all the changes a century has effected, few summers pass in which this delicate and dainty species is not detected, either upon St. Vincent's Rocks or among the bushy slopes adjacent. Woods near Dursley; *Herb. Stephens.*

S. Leigh Wood; constant in several spots, both in deep shade and also on the open stony banks above the river. Many localities near Bath are given in the *Flora Bathoniensis*, and we ourselves have seen it, several years in succession, in and about a wood near Fortnight not far from the *Cephalanthera grandiflora.* Woods at Weston-in-Gordano, constant. "The Fly Orchis grows in Limeridge Wood near Tickenham." *Rutter's Hist. N. W. Somerset.* This statement has been confirmed several times during the last half century, and as lately as June, 1885, by Mr. D. Fry. VI.

HERMINIUM, *R. Br.*

741. **H. Monorchis,** *R. Br.* *Musk Orchis.*

Native; very rare.

conopsea, and about hal
H. Franklin Parsons.

SPIRANT

742. S. autumnalis, *Rich.*

Native; on dry calcareou
Rather common on lin
G. Scattered all over (
noticed to be more
Gardens than elsewhe
S. Leigh Down, in fi
Walton-in-Gordano.
Ellenborough Park,
In several places on
Miss Livett.

LIST

743. L. ovata, *R. Br.* *Tı*
Native; in woods and ı
out the district.

NEC

744. N. Nidus-avis, *Rich*
Native; rather frequ

Wood. Bourton Combe. Ebbor. Hutton. Nightingale Valley, Weston-in-Gordano. Limeridge Wood, Tickenham. Portishead. Paul Wood, between Temple Cloud and Clutton. VI.

EPIPACTIS, *Rich.*

745. E. latifolia, *All.*

Native; in woods, frequent.

G. Abundant in the woods about Dursley. Tortworth. Woods near Wotton-under-Edge.

S. Leigh Wood, rare; one or two plants are found from time to time, as in 1835 by Dr. H. O. Stephens, and at intervals since by other botanists. Ebbor. Bourton Combe. Occasionally near Wells. St. Ann's Wood, Brislington, 1840; *Mr. T. B. Flower.* Brislington, 1885; *Mr. R. Baker.* Woods near Hallatrow and Clutton, plentiful. Several localities are mentioned in *Fl. Bathon.* VII.

746. E. palustris, *Sw.*

Native; in swamps, rare.

S. Abundant in marshy spots amid the sand-hills at Berrow. Formerly in a swamp near Winscombe. Near Weston-super-Mare, *Herb. Stephens;* which may refer to the Berrow station. VII. VIII.

CEPHALANTHERA, *Rich.*

747. C. grandiflora, *Bab.*

Native; in woods, rare.

G. In woods at Tortworth Park.

S. Several localities near Bath are given in the *Fl. Bathon.* and its *Additions.* In one of these (that near Fortnight) we have seen eight or ten plants in 1882 and 1883. In a wood near Clevedon; unsuspected until 1883, when three or four plants were observed. Mr. D. Fry saw seven or eight in 1884. This locality

is a good deal frequented by visitors, and to specify it more exactly would expose the plant to probable destruction. Wick Grove, Brislington. *Dr. Withering. Swete, Fl.* 75. Not mentioned in Withering's 3rd edition. VI.

IRIDACEÆ.

IRIS, *Linn.*

748. I. Pseud-acorus, *L. Yellow Flag.*

Native; in and by water. Very abundant throughout the alluvial portions of the district. VI. VII.

749. I. fœtidissima, *L.*

Native; in woods and hedges, and occasionally on more open ground. Frequent, but mostly in small quantity.

G. In a wood on Spaniorum Hill above Compton Greenfield. Sparingly at Stoke Bishop.

S. Hedges near Bishport. Woods near Clevedon. In thickets on the coast near Woodspring Priory. Slopes on the S.W. of Brean Down, and here and there among the sand-hills towards Burnham. Easton and Wookey, *Miss Livett.* In many places near Bath. *Fl. Bathon.* V.—VII.

AMARYLLIDACEÆ.

NARCISSUS, *Linn.*

750. N. biflorus, *Curt.*

Denizen; in fields and old orchards, rather rare.

G. "Near Stoke Bishop, May, 1839, *Miss Fisher.*" *Herb. Powell.*

S. Ashton Park, *Dr. Stephens.* Open pasture near Dundry Hill. Bourton. Meadows near the Church at Churchill, in plenty. Hutton, *Dr. Stephens.* Uphill,

Mr. T. F. Perkins; and *Dr. St. Brody.* Walton-in-Gordano. Winscombe. "In an old orchard at Pill. *J. Anderson, MSS.*" *New Bot. Guide, Suppl.*

751. **N. Pseudo-narcissus,** *L.* *Daffodil.* *Lent-Lily.*

Native; in pastures and open woods, rather common in Somerset. Where it does occur it usually grows in great abundance.

G. Wood at Henbury, *Herb. Powell.* Sparingly in pasture between Stoke Bishop and Westbury-on-Trym. Filton Meads, *Swete, Fl.*

S. Bishport. Churchill. Plentiful in a pasture on Failand Farm. Leigh Wood! *Rev. C. B. Dunn.* In thick underwood at Churchill Batch. Pensford. Yatton. At Edford in immense profusion, both in woodland and pasture; covering nearly a square mile of country. The "Daffodil Valley," near Sidcot. Here the plant is abundant on wooded slopes and grows over a considerable area. Abundant in some of the other Mendip valleys, notably near Witham, and by Stoke Lane, near Wells. III. IV.

(*N. incomparabilis, N. lobularis, N. poeticus,* and *N. aurantius?* have all been recorded on good authority from localities where they have been introduced from gardens.)

("*Leucojum æstivum,* L., grows in some quantity in one place in Almondsbury parish; but as the snowdrop and large periwinkle are its near neighbours there may once have been a cottage garden on the spot, though not in the recollection of any one living." *Rev. K. A. Deakin;* March, 1879.)

GALANTHUS, *Linn.*

752. G. nivalis, *L.* *Snowdrop.*

Denizen; perfectly naturalized in woods and on hedge-banks in many places, but very seldom in quantity.

G. Almondsbury. Formerly near Sea Mills, *Bot. Guide;* and *S. Rootsey, F.L.S.* Plentiful on a shady slope in Henbury Combe, near Blaise Castle, where it has been known very many years. Formerly in the Powder-House Wood, and woods at Stoke Bishop, *Swete, Fl.* 77.

S. In a hedgebank at Whitchurch; *Rev. W. H. Painter.* Barrow Gurney and Hutton; *Dr. H. O. Stephens.* A few plants on the wooded bank of a stream near Edford, growing with *Ribes nigrum;* March, 1884. By the brooklet below Winscombe, not far from some cottages. Uphill. Goblin Glen, near Yatton. II. III.

ALISMACEÆ.

ALISMA, *Linn.*

753. A. Plantago, *L.* *Water-Plantain.*

Native; in ditches and ponds. Common and generally distributed. The variety *β. A. lanceolata,* With., grows at Baptist Mills, G. VII. VIII.

754. A. ranunculoides, *L.*

Native; in the peaty ditches of the great alluvial tract between the Mendips and the Channel, from Tickenham and Nailsea Moor as far as the district extends to the south-west. Locally common. We have no record for Gloucestershire. VI. VII.

SAGITTARIA, *Linn.*

755. S. sagittifolia, *L.* *Arrowhead.*

Native; in ditches and rivers, rather rare and local.

G. Formerly at Baptist Mills, and in Shirehampton Marshes; *Swete, Fl.* 80. In the river Frome near Stapleton. In the river Avon at Crew's Hole and Conham.

S. In the river Avon and the canal at Bath. In the canal near Radford. Nailsea Moor. Tickenham. Yatton. Marsh ditches in the Cheddar valley extending to the south of Wedmore. VII. VIII.

BUTOMUS, *Linn.*

756. B. umbellatus, *L.* *Flowering Rush.*

Native; in ditches and rivers. Rare in the north of Bristol, but quite common in the southern lowlands.

G. In the river Frome near Stapleton. In the Avon at Crew's Hole.

S. Formerly in Bedminster Meads; *Swete, Fl.* 80. In the canal near Radford. Ditches near Brean, Burnham, and Brent Knoll. Kingston Seymour. Nailsea Moor. Tickenham. Yatton. Weston-super-Mare. Pools and ditches throughout the Cheddar valley, and near Highbridge. VI. VII.

TRIGLOCHIN, *Linn.*

757. T maritimum, *L.*

Native; on the muddy banks of the estuaries, and in salt marshes on the channel shore; marking the tidal limit in both counties. VII. VIII.

758. T. palustre, *L.*

Native; in boggy, wet meadows, and on ditchbanks, frequent.

G. Boiling Well. Hallen bog, near Henbury; *Herb. Powell.* Meadow below Cook's Folly; *Dr. H. O. Stephens.* Olveston. Littleton-on-Severn.

S. Bedminster Meads. Nailsea Moor. Moor at Walton-in-Gordano near Clevedon. Meadows under Crook's Peak. Brean. Burnham. Easton. Uphill. Yatton. Moors south of Wedmore. Frequent on the banks of the river Avon and of the canal at Bath. VI. VII.

ASPARAGACEÆ.

ASPARAGUS, *Linn.*

759. A. officinalis, L.

Denizen; in salt marshes and damp sandy soil near the Channel, rather rare. It is thoroughly naturalized, having been noted in one or two of the localities named nearly two centuries ago. None of our plants are the *A. prostratus*, Dum.

G. "Below Look's Folly, two miles from Bristol; *Mr. Newton.*" *Ray, Syn.* The mis-spelling "Look's" instead of "Cook's" is perpetuated by both Hudson and Withering. "In the salt marshes below Kingsweston, near Bristol." *Withering;* and *Dr. H. O. Stephens,* about 1835. Marsh near Thornbury, *B. G.* We saw a small quantity below Sea Mills in 1877 and 1880.

S. On the grassy bank of Avon opposite Cook's Folly, in several places. Uphill. Salt marsh near Berrow. "Sandbanks at Steart and Burnham, from three to five feet high when in blossom. (Mr. Clark.) *J. C. Collins, MSS.*" *New B. G. Suppl.* Still on sands near Burnham, plentiful in 1884 and 1885, and quite as luxuriant as is stated in the old record. VI.—VIII.

CONVALLARIA, *Linn.*

760. C. majalis, *L. Lily of the Valley.*

Native; in rocky woods, rare. It grows on wooded slopes where the soil is little else than broken limestone com-

pacted with a little loam, from which the roots cannot be disengaged without much labour. We have visited the localities in Leigh Wood and near Wotton-under-Edge. Both these have a north-eastern aspect. With us the plant flowers very sparingly. We feel sure that in a favourable season the yield would not exceed one handful to the acre.

G. Very steep stony slope in Westridge Wood, in plenty.

S. A large patch in Leigh Wood near the Avon. King's Wood, near Yatton; *Miss Winter.* Asham Wood; *Rev. R. Murray.* Wood near Bath; *Add. Fl. Bathon.* V.

POLYGONATUM, *Tourn.*

761. P. officinale, *All. Convallaria Polygonatum,* L.

Native; in rocky woods on limestone, rare. Often associated with the Lily of the Valley. It fruits but seldom.

G. Woods above Wotton-under-Edge in several places.

S. Leigh Wood, by no means extinct, as is feared in *E. B.*, ed. 3; but not so plentiful as formerly, a good deal having been destroyed by quarrying. "Cheddar Cliffs. *W. Christy,* sp. Woods on the N. side of the Mendip Hills; woods at East Harptree, under Mendip. *B. G.*" *New B. Guide.* V.

762. P. multiflorum, *All. Solomon's Seal.*

Native; in woods on limestone, very local.

G. Wood at Dursley, *B. G.*

S. Harptree Combe. Wood at Leigh-on-Mendip. Paul Wood, near Temple Cloud, to 3 ft. 9 in. high, June, 1885; *Mr. D. Fry.* Bishop's Wood, and in one or two other woods near Wells; *Miss Livett.* Abundant in woods from Binegar to Asham; *Rev. R. Murray.* Near Bath; *Fl. Bathon.* Not known in Leigh Wood, where it is likely that *P. officinale* has been mistaken for it. VI.

RUSCUS, *Linn.*

763. R. aculeatus, *L. Butcher's Broom.*

Alien; occasional in hedges and about gardens. Clearly not indigenous with us. III. IV.

LILIACEÆ.

TULIPA, *Linn.*

764. T. sylvestris, *L.*

Doubtfully native in a field near Bath. Plentiful in a meadow by the side of the canal near Combe Hay; now ploughed up, but still occupied by the Tulip, which, as Mr. Flower informs us, did not flower in 1885. "Bitton meadows, Gloucestershire, opposite the church; *Rev. H. J. Ellacombe.*" *With.*, ed. 7., II., 426. An escape, long since extinct. See note by Mr. T. B. Flower in *Phytol.* III., 854.

FRITTILLARIA, *Linn.*

765. F. Meleagris, *L.*

Native; in pastures, probably now extinct.

G. "In a meadow below Winterbourne Church, since ploughed; May, 1859." Note in Dr. Stephens' copy of Withering. In meadows at Bitton, near the Paper Mills. Now extinct. *Mr. T. B. Flower; Phytol.* I., 70.

S. Formerly abundant in a field or fields close to the village of Compton Martin, as recorded in *New B. G.* and by botanists more recently. This locality has been thoroughly searched on two occasions, in 1883 and 1884, but the result was disappointing. We fear there is little doubt that the report current in the neighbourhood is well grounded; and that "Old Henniker," as the former proprietor of the land is irreverently called,

did malevolently grub up and destroy the whole of this beautiful plant, in order that people should no longer annoy him by coming from all the country round to gather it in his fields. We have conversed with old inhabitants of the parish who have pointed out to us the exact spot where they remember to have gathered it, and who say that there were some plants with white flowers. Reported to grow also in meadows in Litton parish, but this we have not been able to inquire into.

ORNITHOGALUM, *Linn.*

766. O. umbellatum, *L.*

Denizen or alien; in meadows or orchards, and about old gardens, very rare.

S. Bishport; *Herb. Stephens.* "In a field near the caisson at Combe Hay, *Dr. Davis.*" *Fl. Bathon.* Also reported from near Combe Hay by Mr. T. B. Flower. Ditchbank at Burnham, not near a house, 1879; *Miss Winter.* Meadow at Uphill; *Dr. St. Brody.* Noted at Walton-in-Gordano by two or three observers; the place being probably the site of an old garden. "On the top of a hill, three miles on this side Bristol"; *Ray. Syn.*, 372. V.

767. O. pyrenaicum, *L.*

Native; in woods and on grassy hedgebanks. Very local, but usually abundant where it does occur.

In our district this species is confined to a narrow tract of country in North Somerset. The neighbourhood of Bath is its headquarters, and it extends from that city about eight miles to the westward, as far as Stockwood, which we believe to be its western British limit.* At

* We may conclude from Ray's mention of this Ornithogalum in the Bristol district that in his time it did not occur further west

this point it approaches within four miles of Bristol. The plant is found at intervals along the lanes from Stockwood to Keynsham, and more abundantly between the latter place and Bath. Here it is met with in profusion in many of the woods; and we have noticed it in plenty as far south as Dunkerton.

The young, unexpanded spikes are sometimes eaten like asparagus. They are to be had in Bath Market and in the shops of the city under the names of "Bath asparagus," "wild asparagus," or "wild grass." Our opinion, on experiment, is that the Bath substitute as "a vehicle for melted butter" is very little inferior to the cultivated esculent. VI.

GAGEA, *Salisb.*

768. G. lutea, *Ker.*

Native; in woods and bushy places, very rare and no longer to be found in some of its old stations.

G. In thickets at Granham Rocks, near Bitton; quite plentiful at one time, but now destroyed by quarrying; *Mr. T. B. Flower.* "Wyck; *Miss Worsley.*" *Bot. Guide.* Wyck; *Mr. S. Rootsey, F.L.S.* Mr. Flower tells us that formerly he found it very sparingly at Wyck, among rocks on the left bank of the stream.

S. St. Ann's Wood, Brislington; *Rev. G. W. Braikenridge.* Brislington; *Mr. S. Rootsey.* It is likely that the plant was extirpated at St. Ann's by the construction of the Great Western Railway, as none has been found there for many years. "Twerton Wood; *Mr. Aldham.*" *Add. Fl. Bathon.* Near Mells; *Rev. R. Murray.*

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than it does now. "*Tho. Willisellus* observavit in colle quodam tribus cis *Bristoliam* milliaribus via qua inde Bathoniam itur." *Ray. Syn.*, 372.

SCILLA, *Linn.*

769. S. autumnalis, *L.*

Native; formerly on St. Vincent's Rocks, and perhaps also on Clifton Down. Ray noticed it upon the Rocks, and many other observers have recorded it from the same place. Specimens from thence are to be seen in most of the local herbaria of the last generation with dates coming up to about 1860. We doubt if it has been seen since the completion of the Clifton Suspension Bridge and its approaches. Our information goes to show that the plant grew plentifully near the Clifton pier of the bridge, and was confined within a very small compass. Swete, however (*Fl.* 78), gives also "the sward on the top of the rocks." We will yet cherish the hope that a few bulbs still remain in some little-trodden morsel of turf; but as year after year passes without a sign of their existence, the probability grows rapidly fainter.

ALLIUM, *Linn.*

770. A. vineale, *L.* *Crow-Garlic.*

Native; in pastures and on dry banks.

The flowering variety (*β. bulbiferum. Syme, E. B.*) is very rare. About twenty well-marked plants were found in August, 1883, growing in loose sandy soil upon a ledge of St. Vincent's Rocks. The form *compactum* is rather common in both counties. VII. VIII.

771. A. sphærocephalum, *L.*

Native; very rare and local.

G. In small quantity on some ledges of St. Vincent's Rocks; perhaps a dozen plants yearly. More plentiful on Durdham Down, nearly a mile away from the first station. Here as many as forty flower-heads have been seen in one season.

This species is one of the gems of the Bristol Flora. We are glad to say it runs no risk of destruction at the hands of the quarryman,—a fate which in *E. B.*, ed. 3, is stated to have already befallen it,—but the more refined weapons of the collector are hardly less deadly, and from these there is danger, unless they be used solely by scientific and unselfish hands. VIII.

772. A. oleraceum, *L.*

Native; in pastures, among rocks, and sometimes in corn-fields, rare. Singularly indifferent to the nature of soil or situation: flourishing alike on limestone rocks and in the rich riverside pasture land.

G. Prope Bristolium copiose; *Huds. Fl. Angl.* Corn-fields at Lawrence Weston, July, 1833; *Herb. Powell.* Stapleton; *Herb. Stephens.* A good patch in a small hollow on Durdham Down, 1882 and 1883. In plenty for half a mile on the bank of Avon near Sea Mills.

S. Ashton fields; *Miss Atwood*, and *Mr. T. B.Flower.* Very abundant in one spot near the encampment on the hill at Weston-super-Mare; but, as might be expected from the nature of the ground, the plants are smaller and less vigorous than those on the Avon bank. *Mr. D. Fry.* VII. VIII.

773. A. ursinum, *L.* *Ramsons.*

Native; very abundant in most woods, copses, &c., throughout the district. V. VI.

ENDYMION, *Dumort.*

774. E. nutans, *Dum.* *Blue-bell.*

Native; in woods and damp shady places, very common. White-flowered plants have been observed at Filton, and between Patchway and Charlton, G.; and in Somerset near Clevedon, and in a wood between Abbot's Leigh and the Tanpits. V.

MELANTHACEÆ.

COLCHICUM, *Linn.*

775. C. autumnale, *L.* *Meadow-Saffron.*

Native; in pastures, woods, and old hedgebanks, rather common.

G. In a pasture close to Westbury-on-Trym. Iron Acton. Tortworth. Yate.

S. Bishport Wood. Brislington. Pastures on Dundry Hill, and on the Bridgwater road under Dundry. Abundant on Failand Farm. Field near Barrow Court in plenty. Clevedon. Keynsham. Portbury. Yatton. Whitchurch. Immense quantities in meadows on Mendip, near Shipham. Shutshelf Wood, near Axbridge. Ball Wood, near Congresbury. Paul Wood, near Temple Cloud. In old lanes on Mendip above Sidcot; and on the rough stony ground at the hill-top towards Churchill. In meadows at Churchill. Frequent about Bath. Cameley. Chew Stoke. Compton Martin. Horrington Bottom; and elsewhere near Wells. Weston-in-Gordano. Wrington. Plants bearing white flowers grow at Sutton, near Chew Magna; near Whitchurch; near Hallatrow; at Chelwood—"dozens of 'em in one place"; also at Whitley Batch, near by, and in meadows at Stanton Prior.

An account of Colchicum flowering in spring (March, 1880), both on Failand Farm and in pastures on the Bridgwater road, will be found in the *Journ. of Bot.* for May, 1880. The author expressed an opinion that this would not prove to be a permanent condition of the plants, but one temporarily induced by the peculiarly early and severe cold of the previous autumn. This view has been justified by subsequent observation. In

the succeeding years the onset of winter was not heralded by frost in September, and no spring-flowering Colchicum has been seen since. IX. X.

NARTHECIUM, *Huds.*

776. **N. ossifragum,** *Huds.* *Bog-Asphodel.*

Native; on boggy hill sides, in elevated bogs on Mendip, and in peaty marshes, rare and local.

S. About the sphagnous, boggy sources of streams on Black Down. In bogs on Mendip, near Priddy and the Mineries. Moors south of Wedmore. VI. VII.

JUNCACEÆ.

JUNCUS, *Linn.*

777. **J. maritimus,** *Sm.*

We cannot find this rush either in Gloucestershire or in Somerset at the stations recorded, and are doubtful if we do right in including the species here. The tract of salt marshes where it is stated to have been found by Mr. Collins is of large extent, and a most suitable locality for the plant. Until further search has been made we must not relinquish our claim to it.

G. Shirehampton Marshes; *Swete, Fl.* 83.

S. Mouth of the Parret, in ditches; not unfrequent near the Channel. *J. C. Collins, MSS.* *New B. G. Suppl.*

778. **J. effusus,** *L.*

Native; in marshes and on damp ground generally. Very common. VII.

779. **J. conglomeratus,** *L.*

Native; in wet places. Common in many parts of the district, but not so well distributed as the last species. VII.

780. J. glaucus, *Sibth.*

Native; in wet places, common. VII.

781. J. obtusiflorus, *Ehrh.*

Native; in marshes, very rare.

G. Ashley (Boiling Well); *Mr. G. H. K. Thwaites* and *Mr. W. E. Green.*

S. Walton Moor; *Herb. Powell.* Yatton; *Miss Winter.*

782. J. acutiflorus, *Ehrh.*

Native; in peaty meadows and damp places, very common. VI.—VIII.

783. J. lamprocarpus, *Ehrh.*

Native; on wet and peaty ground, common. VII. VIII.

784. J. nigritellus, *D. Don.*

Native. It grows abundantly on the marshy sands near Berrow, S. VII. VIII.

785. J. supinus, *Moench.*

Native; in bogs and on peaty moors, rare and local.

S. Bogs on the slopes of Black Down, and about the Mineries. Boggy ravine near Wells. Moors south of Wedmore. VI.—VIII.

786. J. squarrosus, *L.*

Native; on wet heaths and moors, rare and local.

S. Bogs on Mendip at the Mineries and about Black Down. Moor near Clevedon. VI. VII.

787. J. compressus, *Jacq.*

Native; rather rare? We have been favoured with several localities for this rush; but the species is so little understood that we regard them as resting on doubtful authority.

G. Horfield; *Herb. Stephens.*

788. **J. Gerardi,** *Lois.*

Native; in salt marshes and damp places near the coast. Very common in such situations. VI.—VIII.

789. **J. bufonius,** *L.* *Toad-rush.*

Native; in wet places, common.

The Toad-rush, although common enough in many localities, is singularly absent from a few. For instance, it is a rare plant in the vicinity of Clevedon. VII. VIII.

LUZULA, *Cand.*

790. **L. sylvatica,** *Bichen.*

Native; in woods and on shady banks. Very abundant in many places. IV.—VI.

791. **L. pilosa,** *Willd.*

Native; in woods, common. V.

792. **L. campestris,** *Willd.*

Native; in pastures and dry places, very common. IV. V.

793. **L. multiflora,** *Lej.*

Native; in damp peaty places, frequent. Our plant is the form *congesta.*

G. Copse between Horfield and Stapleton; *Herb. Stephens.* Yate Common.

S. On Black Down. Cheddar. Downhead. Wells; *Miss Livett.* Moors south of Wedmore. VI. VII.

TYPHACEÆ.

TYPHA, *Linn.*

794. **T. latifolia,** *L.* *Reed-Mace.*

Native; in ponds and wet swamps, rather common. VI. VII.

795. **T. angustifolia,** *L.*

Native; very rare.

S. In a ditch on the peat moor south of Wedmore; *Mr.*

T. F. Perkins! Formerly in one of the locks on the canal at Combe Hay; *Add. Fl. Bathon.* "Ditches at Burnham and Wembdon; *J. C. Collins, MSS.*" *New B. G. Suppl.*

SPARGANIUM, *L.*

796. **S. ramosum,** *Huds.*

Native; in wet ditches and pools, rather common. VI. VII.

797. **S. simplex,** *Huds.*

Native; in ditches and streams, rare.

G. Baptist Mills; *Dr. Stephens.* Ditches near Stapleton; *Herb. Stephens.*

S. Ditches near Clevedon. Walton-in-Gordano. Nailsea Moor. Draycot. Moors south of Wedmore. In the canal at Radford. Yatton. VII.

(*S. natans,* L., is stated by Swete (*Fl.* 82) to occur in "ditches and marshes," as if common about Bristol. This is an error.)

ARACEÆ.

ACORUS, *Linn.*

798. **A. Calamus,** *L.* *Sweet Flag.*

Alien or denizen; naturalized in one or two places.

S. Banks of the Avon at Batheaston, and between Newton Bridge and Saltford; where it is supposed to have been introduced by the late Mr. Sole. In old turf pits at Wedmore; *Collinson's Hist. Somerset,* 1791.

ARUM, *Linn.*

799. **A. maculatum,** *L.* *Cuckoo-pint.* "*Lords and Ladies.*"

Native; in woods and shady places, and on hedgebanks. Very common. IV. V.

LEMNACEÆ.

LEMNA, *Linn.*

800. L. trisulca, *L.*

Native; on water in ditches and stagnant pools, frequent.

G. Marsh ditches about Avonmouth and Shirehampton.

S. Marsh ditches in the Cheddar valley. Clevedon. Easton. Radford. Weston-super-Mare. Yatton. Ditches south of Wedmore.

801. L. minor, *L.*

Native; very common everywhere on stagnant water.

802. L. gibba, *L.*

Native; on stagnant water, not very common.

G. Plentiful in ditches of brackish water near the Severn, between the Passages and Avonmouth. Horfield. Shirehampton. Westbury-on-Trym.

S. Claverham. Yatton. Marsh ditches in the lowlands towards the Channel.

803. L. polyrrhiza, *L.*

Native; chiefly in the peaty lowlands in the southern portion of the district, rather local.

G. Stapleton. Littleton-on-Severn.

S. Near Brent Knoll. Draycot. Portbury. Wedmore. Yatton.

POTAMOGETONACEÆ.

POTAMOGETON, *Linn.*

804. P. natans, *L.*

Native; in rivers and ponds, rare.

G. In the river Frome near Stapleton. Pond at Henbury.

S. The Abbots' Pond. In the Avon near Brislington. Clevedon. Yatton. VI. VII.

805. P. polygonifolius, *Pourr.*

Native; in ditches and slow streams, frequent.

G. Dursley. Berkeley. Yate Common.

S. In the canal at Radford. South Brent. Pools on Mendip near the Mineries and towards Wells. VII.

806. P. rufescens, *Schrad.*

Native; in slow streams and ditches, rare.

G. Near St. Philip's Marsh; *Dr. H. O. Stephens.*

S. Marsh ditches near Axbridge. VII.

807. P. lucens, *L.*

Native; in rivers and deepish water, frequent.

S. Frequent in the Avon between Bath and Bristol. In the river Brue. In the canal near Radford. Nailsea Moor. VI.

808. P. perfoliatus, *L.*

Native; in deep water, rare.

S. Plentiful in the canal near Bath. In the river Avon at Brislington. VII.

809. P. crispus, *L.*

Native; in ditches and ponds, common. VI.

810. P. pusillus, *L.*

Native; in ditches and ponds, frequent.

G. River Frome near Stapleton; *Mr. G. H. K. Thwaites.*

S. River Avon near the Cotton Mills, and towards Keynsham. In the canal by Bath; *Add. Fl. Bathon.* Yatton. VI.

811. P. pectinatus, *L.*

Native; in marsh ditches, frequent.

G. Ditches in Shirehampton Marshes. St. Philip's Marsh.

S. Ditches near Pill; *Mr. W. E. Green.* Kingston Seymour; *Mr. D. Fry.* VI. VII.

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812. P. densus, *L.*

Native; in ditches and streams, common. VI. VII.

RUPPIA, *Linn.*

813. R. rostellata, *Koch.*

Native.

G. In a brackish pool near the Avon below Shirehampton. V. VIII.

ZANNICHELLIA, *Linn.*

814. Z. palustris, *L.*

Native; in stagnant water, rather common.

G. Abundant in Avonmouth Marshes. Filton Meads. Horfield.

S. Pools at Bedminster and at Whitchurch. Stockwood. Congresbury. Portishead. Yatton. V.—VIII.

NAIADACEÆ.

ZOSTERA, *Linn.*

815. Z. nana, *Roth.*

Native; in the muddy estuaries.

816. Z. marina, *L.*

Native; on the coast of N. Somerset.